Standard Specification for
Tanks, 5 and 10-Gal (20 and 40-L) Lube Oil Dispensing

1. Scope

1.1 This specification covers the material, dimensions, and construction of 5 and 10-gal (20 and 40-L) tanks purchased to store and dispense lubricating oils. The tanks are industrial safety cans mounted on a T-bar bracket, complete with drip tray.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A36M Specification for Carbon Structural Steel
A 108 Specification for Steel Bars, Carbon, Cold Finished, Standard Quality
A 164 Specification for Electrodeposited Coatings of Zinc on Steel
A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
A 308 Specification for Steel Sheet, Cold-Rolled, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process
A 569/A569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial Quality

2.2 ASME Standards:

3. Ordering Information

3.1 Orders for tanks under this specification shall include the following:
3.1.1 Quantity (number),
3.1.2 Size, either 5 or 10 gal (20 or 40 L),
3.1.3 Purchase option for finished tank materials: Terne plate (4.1.3), and
3.1.4 ASTM designation and year of issue.

3.2 If only size, quantity, and ASTM designation are specified and no purchase options are specified, then suppliers shall furnish all stainless steel tanks, brass faucets with flash arrestors, and painted steel mounting columns with bolt-on drip tray assemblies, which include perforated steel tray liners, drain plugs, drilled mounting holes, and mounting bolts.

3.3 Optional packaging/shipping.
3.3.1 If required for shipping, tanks shall be packaged individually in cartons suitable for freight handling.

4. Materials and Manufacture

4.1 Materials:
4.1.1 316 Stainless Steel Sheet (Specification A 167), minimum thickness 24 gage (0.6 mm) on tank body, 22 gage (0.8 mm) on tank top and bottom; body bracket, filler spout, flash arrestor, vacuum breaker valve and linkage.
4.1.2 316 Stainless Steel Cast, Wrought, or Forged Flanges
4.1.3 Terne Plate Sheet (purchase option), minimum thickness 22 gage (0.8 mm) on tank body, top and bottom: body bracket, filler spout (Specification A 308).
4.1.4 Mild Steel:
4.1.4.1 Bolt-On Column Stand, T-section, hot-rolled (Specification A 36/A 36M); minimum thickness 0.160 in. (4 mm).
4.1.4.2 Drip Tray Bracket, round edge, hot-rolled (Specification A 569/A569M).
4.1.4.3 Drip Tray Assembly, hot or cold-rolled (Specification A 108).
4.1.4.4 Drip Tray Liner, 11-gage (3 mm), zinc-plated (Specification A 164).
4.1.4.5 Filler Spout Cover, zinc-plated steel (Specification A 164).
4.1.4.6 Drip Tray Drain, ¼-in. (20 mm) NPS drain.
### Dimensions

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Note 1—Dimensions and construction for guidance only.
Note 2—1 in. = 25.4 mm.
Note 3—1 lb = 0.4536 Kg.

FIG. 1 Dimension of Tank
4.1.5 *Cast Brass:*

4.1.5.1 *Faucet,* lever-lock, self-closing, ¾-in. (20 mm) outside diameter, male threaded.

4.1.5.2 *Drip Tray Drain Plug and Tank Bottom Drain Plug,* ¾-in. (20 mm) NPS.

4.1.6 *Cast Aluminum,* self-closing, spring-action type, one-piece, filler spout cover lever.

4.2 *Manufacture*—All sheet metal seams shall be welded.

5. **Dimensions and Weight**

5.1 The dimensions in Fig. 1 are recommended nominal dimensions. Weights are estimated and are not critical. Volume of tanks shall be 5 and 10 gal (20 and 40 L), respectively.

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*Protectoseal 531G, available from The Protectoseal Co., 225 Foster Ave., Bensenville, IL 60106, or equivalent, has been found suitable for this purpose.*
1. Scope

1.1 This practice lists commonly used types of branch connections for carbon steel, chromium-molybdenum steel pipe and copper-nickel alloy tubing. Branch to run size applications are given in Table 1, Table 2, and Table 3. Other types of branch connections (Fig. 1) may be used provided they comply with the requirements of Title 46 CFR Subparts 56.07-10(f) and 56.70-15(g) of the USCG Regulations.

2. Referenced Documents

2.1 ASTM Standards:
F 722 Specification for Welded Joints for Shipboard Piping Systems

2.2 ANSI Standard:
B31.1 Power Piping

2.3 Other Document:
Title 46 Code of Federal Regulations (CFR) Shipping, Parts 41 to 69

3. General Requirements

3.1 Weld joint designs shall be in accordance with Specification F 722 and the limitations therein.

3.2 Fabricated branch connections shall meet the reinforcement requirements of Section 104.3 of ANSI B31.1 as modified by Title 46, CFR Subparts 56.07-10(f) and 56.70-15(g) of the USCG regulations.

3.3 Threaded fittings shall be subject to the limitations of Title 46 CFR, Subpart 56.30-20 of the USCG Regulations.

4. Keywords

4.1 branch connections; carbon steel connections; chromium-molybdenum steel pipe; copper-nickel alloy tubing

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1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


4 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
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**LEGEND (see Fig. 1)**

1 = Tee or lateral (butt weld)
2 = Tee or lateral (socket weld or threaded)
3 = Welded outlet (butt weld end)
4 = Welded outlet (socket weld or threaded end)
5 = Fabricated joint (cut-in branch)
TABLE 2 Branch Connection Matrix for Chrome Moly Piping

LEGEND (see Fig. 1)

1 = Tee or lateral (butt weld)
2 = Tee or lateral (socket weld)
3 = Welded outlet (butt weld end)
4 = Welded outlet (socket weld end)
5 = Fabricated joint (cut-in branch)
TABLE 3 Branch Connection Matrix for Copper Nickel Piping

LEGEND (see Fig. 1)

1 = Tee or lateral (butt weld)
2 = Tee or lateral (silver brazed)
3 = Welded outlet (butt weld end)
4 = Welded outlet (silver brazed end)
5 = Fabricated joint (cut-in branch)
6 = Silver brazed outlet (silver brazed end)

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F 681 – 82 (1998)
FIG. 1 Illustrative Legend for Branch Connections

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Standard Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings

This standard is issued under the fixed designation F 682; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers wrought carbon steel sleeve-type pipe couplings suitable for joining carbon steel pipes.

1.2 Type I couplings are intended for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight pipe. Type II couplings are intended for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of extra strong pipe.

1.3 This specification does not cover cast steel couplings.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

NOTE 2—See Appendix X1 for rationale used to develop this specification.

2. Referenced Documents

2.1 ASTM Standards:
   - A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
   - A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service
   - A 234/A234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
   - A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
   - E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 Manufacturer’s Standardization Society of the Valve and Fittings Industry Standard:
   - MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.3 ASME Boiler and Pressure Vessel Code:
   - Section VIII Unfired Pressure Vessels
   - Section IX Welding Qualifications

2.4 Federal Regulations:
   - Title 46, Code of Federal Regulations (CFR), Shipping, Parts 41 to 69

2.5 ANSI Standards:
   - B16.5 Pipe Flanges and Flange Fittings

3. Classification

3.1 Couplings are furnished in two types as follows:

3.1.1 Type I—Couplings (see 1.2).

3.1.2 Type II—Couplings (see 1.2).

NOTE 3—Type II couplings may be used in place of Type I couplings for all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight piping through 18 in. or Schedule 40 piping through 16 in.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of couplings of each size and type),

4.1.2 Name of material (sleeve-type pipe couplings),

4.1.3 Size (nominal, see Table 1 and Table 2 and Fig. 1),

4.1.4 Type (see 3.1),

4.1.5 ASTM designation and date of issue.

5. Materials and Manufacture

5.1 Materials—The couplings shall be manufactured from material having a chemical composition conforming to the requirements of 7.1 and with the mechanical properties of Section 9.

5.2 Manufacture—The initial form of the raw material shall be at the discretion of the manufacturer except couplings shall not be machined from unformed plate. The material shall be...
such that the finished couplings conform to all of the specified requirements (see Appendix X2).

5.3 Couplings fabricated by welding shall be (a) made by welders, welding operators, and welding procedures qualified under the provisions of ASME Boiler and Pressure Vessel Code, Section IX; (b) heat treated in accordance with Section 6 of this specification; and (c) nondestructively tested as follows:

### TABLE 1 Dimensions for Type I Couplings (See Fig. 1)

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Dimension A, Inside Diameter, in. (mm)</th>
<th>Dimension B, Outside Diameter, in. (mm)</th>
<th>Dimension C, Thickness, min, in. (mm)</th>
<th>Dimension D, Length, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼</td>
<td>0.589 (15.0)</td>
<td>0.724 (18.4)</td>
<td>0.143 (3.6)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>⅛</td>
<td>0.889 (22.6)</td>
<td>1.099 (27.9)</td>
<td>0.151 (3.9)</td>
<td>½ (32)</td>
</tr>
<tr>
<td>⅛</td>
<td>1.364 (34.6)</td>
<td>1.709 (43.4)</td>
<td>0.173 (4.4)</td>
<td>1 ⅛ (32)</td>
</tr>
<tr>
<td>⅜</td>
<td>1.949 (49.5)</td>
<td>2.424 (61.6)</td>
<td>0.192 (4.9)</td>
<td>1 ⅜ (32)</td>
</tr>
<tr>
<td>⅝</td>
<td>2.924 (74.3)</td>
<td>3.545 (90.0)</td>
<td>0.215 (5.5)</td>
<td>1 ⅝ (32)</td>
</tr>
<tr>
<td>⅜</td>
<td>4.070 (103.4)</td>
<td>4.700 (119.4)</td>
<td>0.261 (6.6)</td>
<td>2 (51)</td>
</tr>
<tr>
<td>⅘</td>
<td>6.720 (170.7)</td>
<td>8.720 (221.5)</td>
<td>0.309 (7.8)</td>
<td>2 ⅛ (64)</td>
</tr>
<tr>
<td>⅝</td>
<td>10.880 (276.4)</td>
<td>11.875 (301.6)</td>
<td>0.348 (8.8)</td>
<td>2 ⅝ (64)</td>
</tr>
<tr>
<td>⅞</td>
<td>14.140 (359.2)</td>
<td>16.160 (410.5)</td>
<td>0.398 (10.1)</td>
<td>3 (64)</td>
</tr>
<tr>
<td>⅞</td>
<td>18.180 (461.8)</td>
<td>19.050 (483.9)</td>
<td>0.435 (11.0)</td>
<td>3 ⅛ (64)</td>
</tr>
</tbody>
</table>

A Tolerances shall be (1) Sizes through 3 in. incl: +0.000, −0.010 in. (+0.000, −0.254 mm); (2) Sizes 3⅛ through 10 in. incl: +0.030, −0.000 in. (+0.762, −0.000 mm); and (3) Sizes above 10 in.: +0.060, −0.000 in. (+1.524, −0.000 mm).

B Tolerances shall be (1) Sizes through 3⅛ in. incl: +0.125, −0.000 in. (+3.175, −0.000 mm) and (2) Sizes above 3⅛ in.: +1.000, −0.000 in. (+25.4, −0.000 mm).

C Tolerances for all sizes shall be +0.250, −0.000 in. (+6.4, −0.000 mm).

### TABLE 2 Dimensions for Type II Couplings (See Fig. 1)

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Dimension A, Inside Diameter, in. (mm)</th>
<th>Dimension B, Outside Diameter, in. (mm)</th>
<th>Dimension C, Thickness, min, in. (mm)</th>
<th>Dimension D, Length, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼</td>
<td>0.589 (15.0)</td>
<td>1.055 (26.8)</td>
<td>0.233 (5.9)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>⅛</td>
<td>0.889 (22.6)</td>
<td>1.156 (29.4)</td>
<td>0.216 (5.5)</td>
<td>1⅛ (32)</td>
</tr>
<tr>
<td>⅛</td>
<td>1.364 (34.6)</td>
<td>1.369 (34.8)</td>
<td>0.240 (6.1)</td>
<td>1⅛ (32)</td>
</tr>
<tr>
<td>⅜</td>
<td>1.949 (49.5)</td>
<td>2.221 (56.4)</td>
<td>0.256 (6.5)†</td>
<td>1⅝ (32)</td>
</tr>
<tr>
<td>⅝</td>
<td>2.924 (74.3)</td>
<td>2.986 (75.8)†</td>
<td>0.281 (7.1)†</td>
<td>2 (64)</td>
</tr>
<tr>
<td>⅝</td>
<td>3.545 (90.0)</td>
<td>3.648 (92.7)†</td>
<td>0.362 (9.2)†</td>
<td>2⅝ (64)</td>
</tr>
<tr>
<td>⅞</td>
<td>4.070 (103.4)</td>
<td>4.340 (109.2)†</td>
<td>0.398 (10.1)†</td>
<td>3 (64)</td>
</tr>
<tr>
<td>⅞</td>
<td>4.570 (116.1)</td>
<td>4.891 (124.2)†</td>
<td>0.411 (10.4)†</td>
<td>3⅛ (64)</td>
</tr>
<tr>
<td>⅚</td>
<td>5.660 (143.8)</td>
<td>5.444 (138.3)</td>
<td>0.437 (11.1)</td>
<td>2 (51)</td>
</tr>
<tr>
<td>⅛</td>
<td>6.720 (170.7)</td>
<td>6.613 (168.0)</td>
<td>0.477 (12.1)</td>
<td>2 (51)</td>
</tr>
<tr>
<td>⅛</td>
<td>8.720 (221.5)</td>
<td>7.657 (195.7)</td>
<td>0.578 (14.7)</td>
<td>2⅛ (64)</td>
</tr>
<tr>
<td>¾</td>
<td>10.880 (276.4)</td>
<td>10.125 (257.2)</td>
<td>0.703 (17.9)</td>
<td>2⅝ (64)</td>
</tr>
<tr>
<td>⅞</td>
<td>12.880 (327.2)</td>
<td>14.150 (359.4)</td>
<td>0.635 (16.1)</td>
<td>3 (64)</td>
</tr>
<tr>
<td>⅞</td>
<td>14.140 (359.2)</td>
<td>15.400 (391.2)</td>
<td>0.630 (16.0)</td>
<td>2⅛ (64)</td>
</tr>
<tr>
<td>⅛</td>
<td>16.160 (410.5)</td>
<td>17.400 (442.0)</td>
<td>0.620 (15.7)</td>
<td>2⅝ (64)</td>
</tr>
<tr>
<td>⅛</td>
<td>18.180 (461.8)</td>
<td>19.400 (492.8)</td>
<td>0.610 (15.5)</td>
<td>3 (64)</td>
</tr>
</tbody>
</table>

A Tolerances shall be (1) Sizes through 3 in. incl: +0.000, −0.010 in. (+0.000, −0.254 mm); (2) Sizes 3⅛ through 10 in. incl: +0.030, −0.000 in. (+0.762, −0.000 mm); and (3) Sizes above 10 in.: +0.060, −0.000 in. (+1.524, −0.000 mm).

B Tolerances shall be (1) Sizes through 10 in. incl: +0.125, −0.000 in. (+3.175, −0.000 mm) and (2) Sizes above 10 in.: +1.000, −0.000 in. (+25.4, −0.000 mm).

C Tolerances for all sizes shall be +0.250, −0.000 in. (+6.4, −0.000 mm).

† Editorially corrected.

F 682 – 82a (1998)
5.3.1 Sizes 3-in. NPS and Below—Radiographically examined throughout the entire length of each fabricated weld in accordance with Paragraph UW-51 of ASME Code, Section VIII.

5.3.2 Sizes 3 partly-in. NPS Through 16-in. NPS—No nondestructive tests required, and

5.3.3 Sizes 18-in. NPS and Above—Any method of nondestructive testing may be used provided the tests are conducted in accordance with the applicable parts of ASME Code, Section VIII.

6. Heat Treatment

6.1 Couplings Made from Plate or Tubular Products:

6.1.1 Couplings machined from tubular products need not be heat treated.

6.1.2 Hot-formed couplings upon which the final forming operation is completed at a temperature above 1150°F (621°C) and below 1800°F (982°C) need not be heat treated provided they are cooled in still air. If the manufacturer elects to heat treat such couplings it shall be by one of the procedures described in 6.3.

6.1.3 Hot-formed couplings finished at a temperature in excess of 1800°F (982°C) shall subsequently be annealed, normalized, or normalized and tempered.

6.1.4 Cold-formed couplings upon which the final forming operation is completed at a temperature below 1150°F (621°C) shall be normalized or shall be stress-relieved at 1100 to 1250°F (593 to 677°C) for 1 h/in. of thickness.

6.1.5 Couplings produced by fusion welding shall be postweld heat treated at 1100 to 1250°F (593 to 677°C), when the nominal wall thickness at the welded joint is ¾ in. or greater.

6.2 Carbon Steel Couplings Made from Forgings—Couplings made from forgings shall subsequently be annealed, normalized, or normalized and tempered.

6.3 Heat Treatment Procedures—Couplings after forming at an elevated temperature shall be cooled to a temperature below the critical range under suitable conditions to prevent injuries by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Couplings that are to be heat treated shall be treated as follows:

6.3.1 Full Annealing—Couplings shall be uniformly reheated to a temperature above the transformation range and, after being held for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

6.3.2 Normalizing—Couplings shall be uniformly reheated to a temperature above the transformation range and subsequently cooled in air at room temperature.

6.3.3 Tempering and Postweld Heat Treatment—Couplings shall be reheated to the prescribed temperature below the transformation range, held at temperature for not less than 1 h/in. of thickness at the thickest section, and cooled in the furnace or in still air.

7. Chemical Requirements

7.1 The couplings shall conform to the requirements as to chemical composition prescribed in Table 3.

7.2 Weld metal used in the construction of the couplings shall be mild steel analysis No. AI of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code.

8. Product Analysis

8.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements specified in Table 3.

8.2 In the event the couplings do not conform to the requirements specified in Table 3, referee analyses shall be made on additional couplings from the same lot in accordance with Practice E 59.

9. Mechanical Properties

9.1 The steel shall conform to the requirements as to tensile properties prescribed in Table 4.

9.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen under load shall be determined.

9.3 Tension tests shall be made on material representative of and in the same condition of heat treatment as the finished coupling.

9.3.1 Records of the tension tests shall be certification that the material of the coupling meets the requirements of this specification provided the heat treatments are the same. If the raw material was not tested, the coupling manufacturer shall perform the required test on material representative of the finished coupling.

9.4 The tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

TABLE 3 Chemical Requirements

<table>
<thead>
<tr>
<th>Composition, max, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Manganese</td>
</tr>
<tr>
<td>Phosphorus</td>
</tr>
<tr>
<td>Sulfur</td>
</tr>
</tbody>
</table>
10. Dimensions and Permissible Variations

10.1 The dimensions and permissible variations for sleeve couplings to this specification are prescribed in Table 1 and Table 2.

11. Workmanship, Finish, and Appearance

11.1 Sleeve couplings shall have a workmanlike finish, free of scale and injurious defects. Ends shall be finished square and without burrs.

12. Hydrostatic Testing

12.1 Hydrostatic testing is not required by this specification.

12.2 All couplings shall be capable of withstanding, without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed in the specification for the pipe with which the fitting is recommended to be used.

13. Product Marking

13.1 Identification marks consisting of the manufacturer’s symbol or name, the ASTM designation number, type, and size shall be legibly stamped on each fitting, and in such a position as not to injure the usefulness of the fitting. SP-25 may be followed except the word “steel” shall not be substituted for the ASTM designation.

13.2 Where couplings are manufactured by an activity for its own use, the marking requirements of 13.1 do not pertain.

14. Keywords

14.1 carbon steel sleeve-type pipe couplings; couplings; pipe couplings; Type I couplings; Type II couplings

APPENDIXES

X1. RATIONALE USED FOR DEVELOPMENT OF SPECIFICATION F 682

X1.1 This specification has been developed to provide two types of couplings. Type I is for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight pipe. Type II is for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of extra strong pipe. Note 3 provides an option that allows the use of Type II couplings in place of Type I couplings, if desired.

X1.2 The design criteria for the couplings is based on CFR Title 46, Subpart 56.70-15(d)3 and 4 as follows:

X1.2.1 For couplings through 3-in. IPS, the clearance between the system pipe outside diameter and the sleeve coupling inside diameter has been held to a maximum of 0.080 in. when considering tolerances to allow these couplings to be used in Class I piping through 3 in. when not subjected to full radiography as allowed by CFR Title 46. The inside diameter of the coupling is therefore equal to the minimum outside diameter of the pipe to be joined +0.080 in. with a tolerance of +0.000, −0.010 in. This provides for a maximum diametral clearance of 0.080 in.

Note X1.1—The minimum outside diameter of the pipe was determined by subtracting the largest minus tolerance from either Specification A 53/A 53M (ABS Grades 1, 2, and 3) or Specification A 106 (ABS Grades 4 and 5).

X1.2.2 The coupling inside diameter and tolerance in sizes 3½ in. and above for use in Class II piping has been taken from ANSI B16.5, Table 9, for slip-on flanges.

X1.2.3 The minimum length of the coupling has been set at 1 in. This satisfies the USCG requirement of ¾-in. minimum depth of pipe insertion when used in Class I piping.

X1.2.4 To meet the USCG requirement that “the fillet weld shall have a throat dimension of not less than the nominal thickness of the pipe or tubing being joined,” a coupling outside diameter of not less than the nominal outside diameter of the system pipe plus two times 1.4 $T$ has been used. ($T$ = nominal pipe thickness.)

X1.2.5 Hoop stress calculations have been performed to ensure that the strength of the coupling is equal to or greater than that of pipe being joined.

X1.3 A tolerance of +0.125, −0.000 in. was established for the outside diameter of couplings through 10 in. and a tolerance of +1.000, −0.000 in. for couplings 12 in. and larger. This allows the use of commercially available tubular products without machining the outside diameter and limits the maximum outside diameter thereby allowing designers to determine the hole size which would be required to pass a coupling through a penetration.

X1.4 Testing heat treatment requirements have been taken from Specification A 234/A 234M as discussed with USCG G-MMT-7/82.

X1.4.1 Radiography requirements have been taken from CFR Title 46, Subpart 56.95 as discussed with USCG G-MMT-7/82.

X1.5 Although marking is not specifically required by USCG, “marking” has been included in the specification to allow for material control and segregation of the couplings in industry.
X2. TUBULAR RAW STOCK MATERIAL SIZES FOR MANUFACTURE OF COUPLINGS

X2.1 Tubular products listed in Table X2.1 may be used for the manufacture of couplings without machining the coupling outside diameter. Other tubular sizes as well as other wrought materials (that is, forging, bars, billets, plate, and so forth, see 5.2) may also be used provided all the requirements of this specification are satisfied.

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Type I Couplings</th>
<th>Type II Couplings</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼</td>
<td>0.875 OD × 0.563 ID</td>
<td>1.062 OD × 0.563 ID</td>
</tr>
<tr>
<td>¾</td>
<td>¾ in. IPS Sch 160</td>
<td>1.188 OD × 0.688 ID</td>
</tr>
<tr>
<td>½</td>
<td>1 in. IPS Sch 160</td>
<td>1.375 OD × 0.875 ID</td>
</tr>
<tr>
<td>¾</td>
<td>1.500 OD × 1.062 ID</td>
<td>1½ in. IPS XX Strong</td>
</tr>
<tr>
<td>1¼</td>
<td>1.750 OD × 1.250 ID</td>
<td>1½ in. IPS Sch 160</td>
</tr>
<tr>
<td>1½</td>
<td>2.125 OD × 1.625 ID</td>
<td>2.250 OD × 1.688 ID</td>
</tr>
<tr>
<td>1</td>
<td>2 in. IPS Sch 80</td>
<td>2.500 OD × 1.937 ID</td>
</tr>
<tr>
<td>2¼</td>
<td>2½ in. IPS Sch 80</td>
<td>3.000 OD × 2.375 ID</td>
</tr>
<tr>
<td>2</td>
<td>3 in. IPS Sch 80</td>
<td>3.750 OD × 2.875 ID</td>
</tr>
<tr>
<td>3½</td>
<td>4.125 OD × 3.500 ID</td>
<td>4.375 OD × 3.500 ID</td>
</tr>
<tr>
<td>3</td>
<td>4.750 OD × 4.000 ID</td>
<td>5.000 OD × 4.000 ID</td>
</tr>
<tr>
<td>4</td>
<td>5.250 OD × 4.500 ID</td>
<td>5 in. IPS Sch 120</td>
</tr>
<tr>
<td>5</td>
<td>6.375 OD × 5.375 ID</td>
<td>6 in. IPS Sch 120</td>
</tr>
<tr>
<td>6</td>
<td>7.500 OD × 6.500 ID</td>
<td>8.000 OD × 8.500 ID</td>
</tr>
<tr>
<td>8</td>
<td>9.625 OD × 8.625 ID</td>
<td>10.250 OD × 8.500 ID</td>
</tr>
<tr>
<td>10</td>
<td>12.000 OD × 10.750 ID</td>
<td>12 in. IPS Sch 120</td>
</tr>
<tr>
<td>12</td>
<td>14 in. IPS Sch 60</td>
<td>16 in. IPS Sch 160</td>
</tr>
<tr>
<td>14</td>
<td>16 in. IPS Sch 100</td>
<td>16 in. IPS Sch 80</td>
</tr>
<tr>
<td>16</td>
<td>18 in. IPS Sch 80</td>
<td>18 in. IPS Sch 80</td>
</tr>
<tr>
<td>18</td>
<td>20 in. IPS Sch 80</td>
<td>20 in. IPS Sch 80</td>
</tr>
</tbody>
</table>
1. Scope

1.1 This practice provides guidance in the selection of types and thicknesses of thermal insulation materials for piping, machinery, and equipment for nonnuclear shipboard applications. Methods and materials for installation, including lagging, are also detailed.

1.2 Supplemental requirements and exceptions to the requirements discussed herein for ships of the U.S. Navy are included in Supplementary Requirements S1.

1.3 Asbestos or asbestos-containing materials shall not be used.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.02 on Insulation/Processes.
2. Referenced Documents

2.1 ASTM Standards:
- A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
- A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvalume) by the Hot Dip Process
- B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
- B 209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]
- C 168 Terminology Relating to Thermal Insulation
- C 195 Specification for Mineral Fiber Thermal Insulating Cement
- C 533 Specification for Calcium Silicate Block and Pipe Thermal Insulation
- C 534 Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
- C 547 Specification for Mineral Fiber Pipe Insulation
- C 552 Specification for Cellular Glass Thermal Insulation
- C 553 Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
- C 610 Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation
- C 612 Specification for Mineral Fiber Block and Board Thermal Insulation

2.2 Federal Specifications:
- HH-P-31 Packing and Lagging Material, Fibrous Glass Metallic and Plain Cloth and Tape
- TT-P-28 Paint, Aluminum, Heat Resisting (1200°F)

2.3 Military Specifications:
- DoD-C-15328 Primer (Wash), Pretreatment (Formula No. 117 for Metals) Metric
- DoD-C-24596 Coating Compounds, Nonflaming, Fire-Protective (Metric)
- DoD-E-24607 Enamel, Interior, Nonflaming (Dry), Chlorinated Alkyd Resin, Semigloss (Metric)
- DoD-I-24688 Type I, Insulation, Polyimide, Sheet and Tube
- MIL-A-3315 Adhesive, Fire-Resistant, Thermal Insulation
- MIL-A-24179 Adhesive, Flexible, Unicellular-Plastic, Thermal Insulation
- MIL-C-2861 Cement Insulation, High Temperature
- MIL-C-19565 Coating Compounds, Thermal Insulation Pipe Covering—Fire and Water-Resistant Vapor Barrier and Weather Resistant
- MIL-C-20079 Cloth, Glass, Tape, Textile Glass and Thread, Glass
- MIL-C-22395 Compound, End Sealing, Thermal Insulation Pipe Covering—Fire, Water, and Weather Resistant
- MIL-I-22023 Insulation Felt, Thermal and Sound Absorbing Felt, Fibrous Glass, Flexible
- MIL-I-2781 Insulation, Pipe, Thermal
- MIL-I-2818 Insulation Blanket, Thermal, Fibrous Material
- MIL-I-2819 Insulation, Block, Thermal
- MIL-I-16411 Insulation, Felt, Thermal, Glass Fiber
- MIL-I-22344 Insulation, Pipe, Thermal, Fibrous Glass
- MIL-P-15280 Plastic Material, Unicellular (Sheets and Tubes)
- MIL-STD-769 Thermal Insulation Requirements for Machinery and Piping
- MIL-STD-2118 Trap, Steam, Angle, Thermostatic

2.4 Other Documents:
- Title 46 Code of Federal Regulations (CFR), Shipping (Parts 164.009 and 164.012)

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2 The latest revision of all referenced documents shall apply.
3 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards, volume information, refer to the standard’s Document Summary page on the ASTM website.
4 Withdrawn.
5 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
3. Terminology

3.1 Definitions—For definitions of terms relating to insulating materials used in this practice, refer to Terminology C 168.

4. Materials and Manufacture

4.1 Insulation and Lagging Material Specifications, as listed in Tables 1-17, describe those materials that are intended for use in the indicated temperature ranges. The specifications and requirements outlined herein are not intended to prevent the use of new test methods or materials, provided that sufficient technical data is submitted to demonstrate that the proposed test method or material is equivalent in quality, effectiveness, durability, and safety to that prescribed by this practice.

<table>
<thead>
<tr>
<th>Temperature Range °F (°C)</th>
<th>Insulation</th>
<th>Specification</th>
<th>Lagging Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 to 40 (−29 to +4)</td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>fibrous glass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>polymide foam</td>
<td>C 1482, Type I, with vapor retarder</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>elastomeric foam plastic</td>
<td>MIL-P-15280, Form T</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td>41 to 125 (5 to 51)</td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>polymide foam</td>
<td>C 1482, Type I, with vapor retarder</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>elastomeric foam plastic</td>
<td>MIL-P-15280, Form T</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>mineral fiber</td>
<td>C 547, Type II</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td>126 to 450 (52 to 232)</td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>polymide foam</td>
<td>C 1482, Type I</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>elastomeric foam plastic</td>
<td>MIL-P-15280, Form T</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>calcium silicate</td>
<td>C 533</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>expanded perlite</td>
<td>C 610</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td>451 to 1050 (233 to 566)</td>
<td>cellular glass, 800°F (427°C) max</td>
<td>C 552, Type II</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>mineral fiber</td>
<td>C 547, Class 2 (850°F [454°C] max) or Class 3</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>calcium silicate</td>
<td>C 533</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
<tr>
<td></td>
<td>expanded perlite</td>
<td>C 610</td>
<td>fiberglass cloth MIL-C-20079, Type I, Classes 3 through 9 commercial</td>
</tr>
</tbody>
</table>

See 5.4.

See Supplementary Requirements S1.5.

See Supplementary Requirements S1.15.
5. General Requirements

5.1 Piping, including valves, fittings, and flanges conveying vapors, gases, or liquids that attain temperatures outside the range from 55 to 125°F (13 to 52°C) during normal operation, shall be insulated except as otherwise stated herein.

5.2 The insulation thicknesses specified in this practice are designed to maintain the surface temperature at or below 125°F (52°C) for fluid temperatures up to 650°F (343°C) with an ambient temperature of 85°F (29°C). For fluid temperatures above 650°F, the surface will be maintained at a maximum of 133°F (56°C).

5.2.1 Insulation thicknesses have been calculated in accordance with the computer programs in Practice C 680.

5.3 Piping and units of equipment with designated internal temperatures of 300°F (149°C) and over shall be insulated from their supports or the supports insulated from the structures to which they are attached where the heat transmitted is objectionable on the opposite side of the structure.

5.4 Insulated piping passing through accommodation, service, and control spaces must be covered with approved incombustible materials which meet 46 CFR, Sections 164.009 and 164.012. Elastomeric foam plastic insulation shall not be used in these spaces.

5.5 Special consideration shall be given to the insulation of integral piping supplied with and mounted on equipment or machinery. In these cases, alternative materials and methods of installation shall be considered provided that they comply with the performance requirements of this practice.

5.6 Minimum insulation requirements have not been established for those surfaces or applications in which insulations had not been specified in past practices. In effect, the following surfaces are excluded from insulation requirements:

5.6.1 Surfaces where application of insulation will affect proper operation.

5.6.2 Equipment, components, and systems designed for the dispersion of heat.

5.6.3 Thermostatic steam traps and 24 in. (620 mm) of piping upstream of traps, which shall not be insulated. When located in areas in which personnel protection is required, expanded metal shields or multilayer glass cloth shall be provided.

5.6.4 Mechanical joints exposed to subatmospheric pressures and those included in the fuel oil service piping from heaters to burners.

5.6.5 Fuel oil piping between headers and burners.

5.6.6 Piping above 125°F (52°C) in bilges, not within watertight enclosures.

5.6.7 Piping in locations in which sweating and resultant rust is not objectionable such as voids, bilges, and shaft alleys, plus

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### TABLE 2 Insulation and Lagging Materials for Pipe, Tubing, and Fittings Used for Weather-Exposed Piping Systems

<table>
<thead>
<tr>
<th>Temperature Range °F (°C)</th>
<th>Insulation</th>
<th>Specification</th>
<th>Lagging Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20 to +40 (−29 to +4)</td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>fibrous glass cloth</td>
</tr>
<tr>
<td></td>
<td>polyimide foam</td>
<td>C 1482, Type I, with vapor retarder</td>
<td>fibrous glass cloth</td>
</tr>
<tr>
<td></td>
<td>perlite</td>
<td>C 610</td>
<td>fibrous glass cloth</td>
</tr>
<tr>
<td>41 to 100 (5 to 37)</td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>polyimide foam</td>
<td>C 1482, Type I, with vapor retarder</td>
<td>fibrous glass cloth</td>
</tr>
<tr>
<td></td>
<td>perlite</td>
<td>C 610</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>calcium silicate</td>
<td>C 533</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>mineral fiber C</td>
<td>C 547, Class 2 or 3</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td>101 to 450 (38 to 232)</td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>polyimide foam</td>
<td>C 1482, Type I</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>perlite</td>
<td>C 610</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>calcium silicate</td>
<td>C 533</td>
<td>corrosion-resistant steel</td>
</tr>
<tr>
<td></td>
<td>mineral fiber C</td>
<td>C 547, Class 2 or 3</td>
<td>corrosion-resistant steel</td>
</tr>
</tbody>
</table>

A Insulation and lagging materials listed are acceptable for the temperature ranges indicated; other materials are capable of being used provided the requirements of this practice are satisfied.

B See Supplementary Requirements S1.15.

C See Supplementary Requirements S1.5.
plumbing fixtures and associated supply and drain piping immediately adjacent thereto.

5.6.8 Deadend hot water piping 3/8 in. (10 mm) and smaller.

5.6.9 Pressure-gage piping.

5.6.10 Soot-blower valve units and soot-blower flanges.

5.6.11 Piping in voids and cofferdams except where omitting insulation is detrimental to system operation, such as catapult steam.

5.6.12 Safety valve bodies, springs, and lifting gear.

5.6.13 Piping over shower stalls and behind and under lavatories.

5.6.14 Valves or flanges in the collection holding tank (CHT) system.

5.7 Higher-temperature-type insulations are capable of being used where lower-temperature-type insulations are specified, provided that they are satisfactory in all other respects.

5.8 In “high traffic” locations in which the completed insulation and lagging is liable to abuse, such as shipping, unshipping, and maintenance areas, protective sheet metal lagging shall be installed. Where metal lagging is required, any of the materials listed

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### TABLE 3 Insulation and Lagging Materials for Machinery and Equipment

<table>
<thead>
<tr>
<th>Temperature Range °F (°C)</th>
<th>Insulation</th>
<th>Specification</th>
<th>Lagging</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>−20 to +40 (−29 to +4)</td>
<td>elastomeric foam plastic</td>
<td>MIL-P-15280, Form S</td>
<td>fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>polyimide foam</td>
<td>C 1482, Type I</td>
<td>fibrous glass cloth with vapor retarder</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>cellular glass</td>
<td>C 552, Type II</td>
<td>sheet steel galvanized</td>
<td>commercial C</td>
</tr>
<tr>
<td>41 to 125 (5 to 51)</td>
<td>elastomeric foam plastic</td>
<td>MIL-P-15280, Form S</td>
<td>fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>polyimide foam</td>
<td>C 1482, Type I</td>
<td>fibrous glass cloth with vapor retarder</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>cellular glass</td>
<td>C 552, Type I</td>
<td>fibrous glass cloth, or sheet steel black</td>
<td>commercial</td>
</tr>
<tr>
<td></td>
<td>mineral fiber blanket</td>
<td>C 553</td>
<td>sheet steel black, commercial or fibrous glass cloth with vapor retarder</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td>126 to 1200 (52 to 649)</td>
<td>fibrous glass felt</td>
<td>MIL-I-16411, Type II</td>
<td>fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 7 or 9</td>
</tr>
<tr>
<td></td>
<td>polyimide foam C 400°F (204°C) max</td>
<td>C 1482, Type I</td>
<td>fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 8</td>
</tr>
<tr>
<td></td>
<td>refractory fiber blanket</td>
<td>C 892, Grade 6 or 8</td>
<td>sheet steel black commercial or fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>elastomeric foam plastic C 180°F [82°C] max</td>
<td>MIL-P-15280 sheet</td>
<td>fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>high-temperature insulating cement</td>
<td>C 195</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>calcium silicate insulating block</td>
<td>C 553</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mineral fiber blanket C 1000°F [538°C] max</td>
<td>C 553, C 612</td>
<td>sheet steel black, or fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
<tr>
<td></td>
<td>perlite</td>
<td>C 610</td>
<td>fibrous glass cloth</td>
<td>MIL-C-20079, Type I, Classes 3 through 9</td>
</tr>
</tbody>
</table>

A See 5.4.

B Insulation and lagging materials are acceptable for the temperature ranges indicated; other materials are capable of being used provided the requirements of this practice are satisfied.

C With or without rewettable adhesive.

D See Supplementary Requirements S1.15.

E When insulating cement is used, it shall be applied in successive layers, 1/2 to 1 in. (13 to 25 mm) in thickness, until the total thickness specified in Table 7 has been reached. Galvanized iron wire netting, 1-in. (13-mm) mesh, shall be installed between layers. A 1/2-in. (13-mm) thickness of finishing cement, in accordance with Specification C 449/C 449M, shall be applied over the last layer of insulating cement.

plumbing fixtures and associated supply and drain piping immediately adjacent thereto.

5.6.8 Deadend hot water piping 3/8 in. (10 mm) and smaller.

5.6.9 Pressure-gage piping.

5.6.10 Soot-blower valve units and soot-blower flanges.

5.6.11 Piping in voids and cofferdams except where omitting insulation is detrimental to system operation, such as catapult steam.

5.6.12 Safety valve bodies, springs, and lifting gear.

5.6.13 Piping over shower stalls and behind and under lavatories.

5.6.14 Valves or flanges in the collection holding tank (CHT) system.

5.7 Higher-temperature-type insulations are capable of being used where lower-temperature-type insulations are specified, provided that they are satisfactory in all other respects.

5.8 In “high traffic” locations in which the completed insulation and lagging is liable to abuse, such as shipping, unshipping, and maintenance areas, protective sheet metal lagging shall be installed. Where metal lagging is required, any of the materials listed
in Table 13 are acceptable, except for boiler uptake applications in which metal lagging shall be galvanized sheet steel, in accordance with Specification A 653/A 653M, with Coating Designation G-115, and not less than 1⁄32 in. (0.8 mm) thick.

5.9 Before installing insulation, surface preparation of the piping is to be accomplished in accordance with the ship’s painting schedule.

5.10 Lacing hooks shall be welded to the structure or equipment (with permission of the vendor of the equipment) for securing insulation to the equipment.

5.11 For bends, fittings, and so forth, where molded sections of pipe insulation cannot be used, mitered sections of the pipe insulation or premolded fittings and covers shall be used, provided that they are suitable for the temperature and that the requirements of this practice are satisfied (see 4.1 and 5.4). Fittings in sizes under 2-in. (51–mm) nominal pipe size (NPS) shall be insulated with insulating cement, in accordance with Specification C 449/C 449M.

5.12 Where insulation specifications listed in Tables 1 and 3 provide for the use of nonmetal “jacketed”-type insulation, separate lagging material shall be omitted.

5.13 Single-layered insulation construction shall be permitted on all surfaces operating at temperatures below 600°F (316°C). Double-layered insulation construction shall be used with all joints staggered on all surfaces operating at temperatures of 600°F and above, except single-layered construction will be permitted when the total insulation thickness is 3 in. (75 mm) or less or the pipe size is NPS 2 in. (50 mm) or below.

6. Selection Requirements, Piping

6.1 Interior Piping, Temperature Range from −20 to +40°F (−29 to +4°C)—Use for air conditioning and ship’s stores refrigerant piping and other services within the temperature range.

6.1.1 For insulation and lagging materials, see Table 1.

6.1.2 For insulation thickness, see Table 4 or Table 5.

### TABLE 4 Thickness of Cellular Glass Insulation for Piping, −20 to 800°F (−29 to 427°C)

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in. (mm)</th>
<th>Maximum Temperature, °F (°C)</th>
<th>Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄4 (6) and above</td>
<td>21⁄2 (63)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>1⁄4 (38) and below</td>
<td>21⁄2 (63)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>2 (51)</td>
<td>21⁄2 (63)</td>
<td>2 (51)</td>
</tr>
<tr>
<td>21⁄2, 3 (63, 76)</td>
<td>21⁄2 (63)</td>
<td>2 (51)</td>
</tr>
<tr>
<td>4 (102)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>5, 6 (127, 152)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>8 (203)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>10 (254)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>12 (305)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>14 (356)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>16 (406)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
<tr>
<td>18 (457)</td>
<td>21⁄2 (63)</td>
<td>21⁄2 (63)</td>
</tr>
</tbody>
</table>

A Thickness of cellular glass, in accordance with Specification C 552, Type II.
B For refrigerant piping.
C For antisweat applications.
D Thickness for applications in air-conditioned spaces only.

### TABLE 5 Thickness of Elastomeric Foam Plastic Insulation Piping, −20 to 180°F (−29 to 82°C)

<table>
<thead>
<tr>
<th>Nominal Size, in. (mm)</th>
<th>Temperature Range, °F (°C)</th>
<th>Nominal Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-conditioned spaces</td>
<td>Air conditioned spaces only</td>
</tr>
<tr>
<td>1⁄4 (6) and above</td>
<td>−20 to 40°F (−29 to 4°C)</td>
<td>1⁄4 (38)</td>
</tr>
<tr>
<td>1⁄4 (38) and below</td>
<td>−20 to 40°F (−29 to 4°C)</td>
<td>1⁄4 (38)</td>
</tr>
<tr>
<td>2 (51)</td>
<td>41 to 125°F (5 to 52°C)</td>
<td>1⁄4 (19)</td>
</tr>
<tr>
<td>21⁄2, 3 (63, 76)</td>
<td>41 to 125°F (5 to 52°C)</td>
<td>1⁄4 (19)</td>
</tr>
<tr>
<td>4 (102)</td>
<td>126 to 180°F (53 to 82°C)</td>
<td>1⁄8 (13)</td>
</tr>
<tr>
<td>5, 6 (127, 152)</td>
<td>126 to 180°F (53 to 82°C)</td>
<td>1⁄8 (13)</td>
</tr>
</tbody>
</table>

A Thickness of elastomeric foam plastic insulation, conforming with MIL-P-15280, Form T.
B For refrigerant piping.
C For antisweat applications.
D Thickness for applications in air-conditioned spaces only.
6.1.3 For installation details, see Fig. 1, Fig. 2, or Fig. 3 as applicable.

6.2 Interior Piping, Temperature Range from 41°F to 125°F (5 to 52°C)—Use for cold freshwater, plumbing drains, firemain, main and auxiliary, saltwater circulating, and saltwater cooling, piping, and other services within the temperature range.

6.2.1 For insulation and lagging materials, see Table 1.

6.2.2 For insulation thickness, see Table 2, Table 3, or Table 4.

6.2.3 For installation details, see Fig. 1, Fig. 2, or Fig. 3 as applicable.

6.2.4 Special Conditions:

6.2.4.1 Piping systems operating in this temperature range including water closet drain piping do not require insulation except where damage or discomfort will result from condensation.

### TABLE 6 Thickness of Polyimide Foam Insulation Piping, –20 to 400°F (–29 to 204°C)

<table>
<thead>
<tr>
<th>Nominal Size, in. (mm)</th>
<th>Temperature Range, °F (°C)</th>
<th>Non-conditioned spaces</th>
<th>Air conditioned spaces only</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄4 (6) and above</td>
<td>–20 to 40 (-29 to 4)</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>1⁄4 (6) and above</td>
<td>–20 to 40 (-29 to 4)</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>(29 to 41)</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>41 to 60</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>61 to 125</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>126 to 180</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>181 to 250</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>251 to 350</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>351 to 400</td>
<td>1⁄4 (38)</td>
<td>1 (25)</td>
</tr>
</tbody>
</table>

A Thickness of polyimide foam insulation conforming with Specification C 1482.
B For refrigerant piping.
C For antisweat applications.
D Thickness for applications in air conditioned spaces only.

### TABLE 7 Thickness of Mineral Fiber Insulation for Hot Piping, 850°F (454°C) Maximum

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in. (mm)</th>
<th>Maximum Temperature, °F (°C)</th>
<th>Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 (66)</td>
<td>250 (121)</td>
<td>350 (177)</td>
</tr>
<tr>
<td>1 1⁄2 (38) and below</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>2 (51)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>2 1⁄2 , 3 (63, 76)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>4 (102)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>5, 6 (127, 152)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>8 (203)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>10 (254)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>12 (305)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>14, 16, 18 (356, 406, 457)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
</tbody>
</table>

A Commercially known as fibrous glass.
B Thickness of mineral fiber insulation in accordance with Specification C 547, Class 2.
6.4.2 Dry firemain need only be insulated above ceilings and in areas in which damage or discomfort from condensation is a problem.

6.4.3 If cold, fresh, or potable water tanks (not having a side integral with the shell) are installed in a heated area, the piping to the pumps and therefore to the services need not be insulated. If this water is being used for flushing water closets, the drain piping need not be insulated. If this water is being used for flushing water closets, the drain piping need not be insulated. If this water is being used for flushing water closets, the drain piping need not be insulated.

6.4.4 Freshwater fill piping inside the ship shall be insulated.

6.4.5 Drains from drinking water chillers shall be insulated.

6.3 Interior Piping, Temperature Range from 126 to 450°F (52 to 232°C)—Use for hot freshwater, hot-water heating, fuel oil service discharge from heaters to headers, condensate, and air ejector piping, boiler feed, high- and low-pressure steam drain piping, and other services within the temperature range.

6.3.1 For insulation and lagging materials, see Table 1.

6.3.2 For insulation thickness, see Table 4, Table 5, Table 7, Table 8, or Table 9.

6.3.3 For installation details, see Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, or Fig. 6, as applicable.

6.3.4 Special Conditions—On piping, tubing, and fittings sized less than NPS ½ in., insulation need be applied only where required for personnel protection.

6.4 Interior Piping, Temperature Range from 451 to 1200°F (233 to 649°C)—Use for main steam, auxiliary steam, exhaust and bleed steam, gland seal steam and exhaust, high- and low-pressure steam drains, soot blower steam, boiler blow, safety and relief valves escape steam heating, diesel exhaust piping, and other services within the temperature range.

6.4.1 For insulation and lagging materials, see Table 1.
6.4.2 For insulation thickness, see Table 4, Table 7, Table 8, or Table 9, as applicable.

6.4.3 For installation details, see Fig. 1, Fig. 4, Fig. 5, or Fig. 6, as applicable.

6.4.4 Special Conditions:

6.4.4.1 The soot blower piping between the root valve and the soot blower heads shall have an insulation thickness of one half of that indicated for a continually operating system at the same temperature.

6.4.4.2 Main steam piping insulation shall be arranged with removable pads to bare sections for audio gaging when required.

6.4.4.3 Turbogenerator exhaust to main and auxiliary condensers do not require insulation except in areas susceptible to personnel contact.

6.4.4.4 Safety and relief valve escape piping need not be insulated except in areas susceptible to contact by personnel.

6.4.4.5 Boiler blow piping need not be insulated except in areas susceptible to contact by personnel.

6.4.4.6 On piping, tubing, and fittings sizes less than NPS 3/8 in. (10 mm), insulation need be applied only where required for personnel protection.

6.4.4.7 Steam smothering and steam to the sea chests need be insulated only in those areas susceptible to personnel contact.

### Table 11: Thickness of Antisweat Insulation for Machinery and Equipment

<table>
<thead>
<tr>
<th>Temperature Range, °F (°C)</th>
<th>Material Specification</th>
<th>Nominal Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconditional Spaces</td>
<td>Conditioned Spaces</td>
<td></td>
</tr>
<tr>
<td>-20 to +40 (−29 to +4)</td>
<td>elastomeric foam plastic, C 534, Type II</td>
<td>2 (51)</td>
</tr>
<tr>
<td></td>
<td>polyimide foam, C 1482, Type I with vapor retarder</td>
<td>2 (51)</td>
</tr>
<tr>
<td></td>
<td>cellular glass, C 552, Type I elastomeric foam plastic, C 534, Type II</td>
<td>3 (76)</td>
</tr>
<tr>
<td></td>
<td>polyimide foam, C 1482, Type I with vapor retarder</td>
<td>1 (25)</td>
</tr>
<tr>
<td>41 to 125 (5 to 51)</td>
<td>cellular glass, C 552, Type I</td>
<td>1 (25)</td>
</tr>
<tr>
<td></td>
<td>mineral fiber blanket, C 553, C 612</td>
<td>1 (25)</td>
</tr>
</tbody>
</table>

A Nominal thickness exclusive of vapor retarder.

### Table 12: Thickness of Insulating Materials for Hot Surfaces of Machinery and Equipment, 126 to 1200°F (52 to 649°C)

<table>
<thead>
<tr>
<th>Material</th>
<th>Maximum Temperature, °F (°C)</th>
<th>Nominal Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrous glass felt, MIL-I-16411, Type II</td>
<td>150 (66)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>Block calcium silicate, C 533</td>
<td>250 (121)</td>
<td>1 1/2 (38)</td>
</tr>
<tr>
<td>Block perlite, C 610</td>
<td>350 (177)</td>
<td>2 1/2 (63)</td>
</tr>
<tr>
<td>Refractory fiber, C 892, Grade 6</td>
<td>450 (232)</td>
<td>3 (76)</td>
</tr>
<tr>
<td>Refractory fiber, C 892 Grade 8</td>
<td>550 (288)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>Refractory fiber, C 892 Grade 8</td>
<td>650 (343)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>Refractory fiber, C 892 Grade 8</td>
<td>750 (399)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>Refractory fiber, C 892 Grade 8</td>
<td>850 (454)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>Refractory fiber, C 892 Grade 8</td>
<td>950 (510)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>Refractory fiber, C 892 Grade 8</td>
<td>1050 (566)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>Mineral fiber, C 553</td>
<td>150 (66)</td>
<td>1 1/2 (38)</td>
</tr>
<tr>
<td>Elastomeric foam, C 534, Type II</td>
<td>250 (121)</td>
<td>2 1/2 (63)</td>
</tr>
<tr>
<td>Polymide foam, C 1482</td>
<td>350 (177)</td>
<td>3 1/2 (89)</td>
</tr>
<tr>
<td>Insulating cement, C 195</td>
<td>450 (232)</td>
<td>4 1/2 (114)</td>
</tr>
<tr>
<td></td>
<td>550 (288)</td>
<td>5 1/2 (140)</td>
</tr>
<tr>
<td></td>
<td>650 (343)</td>
<td>6 1/2 (165)</td>
</tr>
</tbody>
</table>

A Does not include finishing cement.

### Table 13: Metal Lagging Materials

<table>
<thead>
<tr>
<th>Material Specification</th>
<th>Nominal Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-dipped galvanized steel, A 526/A 526M Coating designation G-115</td>
<td>0.014 (0.356)</td>
</tr>
<tr>
<td>Aluminum, B 209, 6061</td>
<td>0.030 (0.762)</td>
</tr>
<tr>
<td>Corrosion-resistant steel, A 167, Type 304</td>
<td>0.014 (0.356)</td>
</tr>
</tbody>
</table>

A For use on piping and machinery insulation in locations where insulation is subject to abuse, except for uptake applications in which metal lagging shall be galvanized steel, Specification A 526/A 526M, Coating Designation G-115, not less than 1/32 in. (0.795 mm) thick.
6.5 Weather-Exposed Piping, Temperature Range from \(-20\) to \(+40\)\(^\circ\)F (\(-29\) to \(+4\)\(^\circ\)C)—Use for low-temperature piping exposed to the weather.

6.5.1 For insulation and lagging materials, see Table 2.

6.5.2 For insulation thickness, see Table 4.

6.5.3 For installation details, see Fig. 3, Fig. 7, or Fig. 8.

6.5.4 Special Conditions:

6.5.4.1 Piping exposed to the weather shall also be effectively insulated against freezing. The thickness of insulation required to prevent freezing is determined by calculation based on the system fluid, system velocity, type of insulation to be used, and climatic conditions involved. This does not apply to systems that are secured and drained.

6.5.4.2 At pipe supports, remove only enough insulation to provide a snug fit. Fill voids between insulation and support with tightly packed fibrous glass felt, conforming with MIL-I-16411, Type II, to within \(\frac{1}{4}\) in. (6 mm) of the insulation surface. Fill the remainder with end-sealing compound, conforming with MIL-C-22395, overlapping both the support member and the adjacent insulation. Lag and coat with the same materials as the adjacent pipe.

---

### TABLE 14 Thickness of Fiberglass Felt for Removable Insulation Blankets\(^4\)

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in. (mm)</th>
<th>Maximum Temperature, °F (°C) × Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 (66)</td>
<td></td>
</tr>
<tr>
<td>250 (121)</td>
<td></td>
</tr>
<tr>
<td>350 (177)</td>
<td></td>
</tr>
<tr>
<td>450 (232)</td>
<td></td>
</tr>
<tr>
<td>550 (288)</td>
<td></td>
</tr>
<tr>
<td>650 (343)</td>
<td></td>
</tr>
<tr>
<td>750 (399)</td>
<td></td>
</tr>
<tr>
<td>850 (454)</td>
<td></td>
</tr>
<tr>
<td>950 (510)</td>
<td></td>
</tr>
<tr>
<td>1050 (566)</td>
<td></td>
</tr>
</tbody>
</table>

---

### TABLE 15 Thickness of 8–lb/ft\(^3\) (128–kg/m\(^3\)) Refractory Fiber Blanket for Removable Insulation Blankets\(^4\)

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in. (mm)</th>
<th>Maximum Temperature, °F (°C) × Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 (66)</td>
<td></td>
</tr>
<tr>
<td>250 (121)</td>
<td></td>
</tr>
<tr>
<td>350 (177)</td>
<td></td>
</tr>
<tr>
<td>450 (232)</td>
<td></td>
</tr>
<tr>
<td>550 (288)</td>
<td></td>
</tr>
<tr>
<td>650 (343)</td>
<td></td>
</tr>
<tr>
<td>750 (399)</td>
<td></td>
</tr>
<tr>
<td>850 (454)</td>
<td></td>
</tr>
<tr>
<td>950 (510)</td>
<td></td>
</tr>
<tr>
<td>1050 (566)</td>
<td></td>
</tr>
</tbody>
</table>

---

### TABLE 16 Thickness of 6–lb/ft\(^3\) (96–kg/m\(^3\)) Refractory Fiber Blanket for Removable Insulation Blankets\(^4\)

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in. (mm)</th>
<th>Maximum Temperature, °F (°C) × Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 (66)</td>
<td></td>
</tr>
<tr>
<td>250 (121)</td>
<td></td>
</tr>
<tr>
<td>350 (177)</td>
<td></td>
</tr>
<tr>
<td>450 (232)</td>
<td></td>
</tr>
<tr>
<td>550 (288)</td>
<td></td>
</tr>
<tr>
<td>650 (343)</td>
<td></td>
</tr>
<tr>
<td>750 (399)</td>
<td></td>
</tr>
<tr>
<td>850 (454)</td>
<td></td>
</tr>
<tr>
<td>950 (510)</td>
<td></td>
</tr>
<tr>
<td>1050 (566)</td>
<td></td>
</tr>
</tbody>
</table>

---

\(^{4}\) Thickness of fiberglass felt, in accordance with MIL-I-16411, Type II.

\(^{5}\) Thickness of 8–lb/ft\(^3\) (128–kg/m\(^3\)) refractory fiber blanket in accordance with Specification C 892, Grade 8.

\(^{6}\) Thickness of 6–lb/ft\(^3\) (96–kg/m\(^3\)) refractory fiber blanket in accordance with Specification C 892, Grade 6.
6.6 Weather-Exposed Piping, Temperature Range from 41 to 450°F (5 to 232°C)—Use for hot piping systems exposed to weather.

6.6.1 For insulation and lagging materials, see Table 2.

6.6.2 For insulation thickness, see Table 4, Table 7, Table 8, or Table 9.

6.6.3 For installation details, see Fig. 3, Fig. 7, or Fig. 8.

6.6.4 Special Conditions:

6.6.4.1 Piping exposed to the weather shall be effectively insulated against freezing. The thickness of insulation required to prevent freezing is determined by calculation based on the system fluid, system velocity, type of insulation to be used, and climatic conditions involved. This does not apply to systems that are secured and drained.

6.6.4.2 At pipe supports, remove only enough insulation to provide a snug fit. Fill voids between the insulation and support with tightly packed fibrous glass felt, conforming with MIL-I-16411, Type II, to within 1/4 in. (6 mm) of the insulation surface. Fill the remainder with end-sealing compound, conforming with MIL-C-22395, overlapping both the support member and the adjacent insulation. Lag and coat with the same materials as the adjacent pipe.

7. Selection Requirements, Machinery and Equipment

7.1 Temperature Range from −20 to +40°F (−29 to +4°C)—Use for refrigerant and other equipment within the temperature range.

7.1.1 For insulation and lagging materials, see Table 3.

7.1.2 For insulation thickness, see Table 11.

7.1.3 For installation details, see Fig. 9, Fig. 10, or Fig. 11, as applicable.

7.2 Temperature Range from 41 to 125°F (5 to 52°C)—Use for low-temperature machinery and equipment within the temperature range.

7.2.1 For insulation and lagging materials, see Table 3.

7.2.2 For insulation thickness, see Table 11.

7.2.3 For installation details, see Fig. 9, Fig. 10, Fig. 11, or Fig. 12, as applicable.

7.2.4 Special Conditions—Machinery or equipment operating in this temperature range does not require insulation except where damage or discomfort will result from condensation.

7.3 Temperature Range from 126 to 1200°F (52 to 649°C)—Use for medium- and high-temperature machinery and equipment within the temperature range.

7.3.1 For insulation and lagging materials, see Table 3.

7.3.2 For insulation thickness, see Table 12.

7.3.3 For installation details, see Fig. 10, Fig. 11, Fig. 12, Fig. 13, or Fig. 14, as applicable.

8. Insulation and Lagging Requirements for Removable Covers for Valves, Fittings, Flanges, and Machinery or Equipment

8.1 Removable Covers—Flanged valves and fittings and pipeline flanges shall have removable covers to permit servicing of takedown joints.
8.1.1 Removable covers shall be manufactured using materials specified in 8.2-8.4 and to thicknesses specified in Tables 4-7. Stitching, lacing, and quilting (required to prevent sagging) shall be accomplished with materials specified in 8.5 and as shown in Figs. 15-17.

8.1.2 Removable covers are also be manufactured from segments of block insulation or from preformed sectional pipe covering and molded (premolded) components. When a removable cover is made of segments of block insulation or preformed (premolded) sectional pipe covering, it shall be of the same material and thickness as the adjoining pipe insulation.

8.2 Filler Materials for Removable Blankets:
8.2.1 Fibrous glass felt, conforming with MIL-I-16411, Type II.
8.2.2 Refractory fiber blanket, in accordance with Specification C 892, Grade 8.
8.2.3 Refractory fiber blanket, also in accordance with Specification C 892, Grade 6.
8.2.4 Mineral fiber blanket, in accordance with Specification C 612, Class 4.

8.3 Covering or Encapsulating Materials for Removable Blankets:
8.3.1 For surface temperatures 450°F (232°C) and below, the filler shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9 (see Fig. 18, Detail A).
8.3.2 For surface temperatures above 450°F (232°C), the entire outside surface shall be encapsulated with TY304 stainless steel wire mesh, 0.011-in. (0.25 mm) diameter, No. 60 density, and crimped (see Fig. 18, Detail B). Alternatively, the entire outside
surface shall be encapsulated with fiberglass cloth, inserted with stainless steel reinforcement, in accordance with HH-P-31, Type I, Class 1.

8.3.3 The cold or top side of the surface shall be covered with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9. The bottom and side surface areas shall be covered as follows:

8.3.3.1 Fiberglass cloth, shall be inserted with stainless steel wire reinforcement, conforming with HH-P-31, Type I, Class 1 (see Fig. 18, Detail C); or

8.3.3.2 Fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9, with TY304 stainless steel wire mesh, 0.008-in. (0.21-mm) diameter and No. 60 density, shall be crimped sewn onto the fibrous cloth (see Fig. 18, Detail D); or

8.3.3.3 TY304 stainless steel wire mesh, 0.011-in. (0.25-mm) diameter and No. 60 density, shall be crimped (see Fig. 18, Detail E).

8.4 Alternative Covering Materials (for surface temperatures 450°F (232°C) and below, and for cold or top-side covering for temperatures above 450°F), are provided for removable blankets to be used in areas exposed to weather or where liquid penetration

FIG. 2 Installation of Elastomeric Foamed Plastic Insulation (MIL-P-15280 or EB 4013)
8.4.1 Silicone-impregnated fiberglass cloth,
8.4.2 Silicone-impregnated fiberglass cloth with aluminized facing on one side, and
8.4.3 Fiberglass cloth with aluminum or stainless steel facing laminated to one side.

8.5 Hardware and Accessory Items for Removable Blanket Construction—Necessary items shall include blanket lacing devices, blanket quilting devices, stitching materials, and installation materials.

8.5.1 Blanket Lacing Devices:
8.5.1.1 TY304 stainless steel lacing rings with lacing washers (see Fig. 19).
8.5.1.2 TY304 stainless steel lacing hooks with lacing washers (see Fig. 20).
8.5.1.3 TY303 stainless steel lacing capstan assembly sets (see Fig. 21).
8.5.1.4 TY304 stainless steel mechanical hook sets (see Fig. 22).

8.5.2 Blanket Quilting Devices:
8.5.2.1 TY304 stainless steel mechanical quilt sets (see Fig. 23).
8.5.2.2 TY304 stainless steel lacing washers with lacing wire (see Fig. 23).

8.5.3 Stitching Materials:

FIG. 3 Installation of Polyimide Foam Insulation (Specification C 1482)
8.5.3.1 TY304 stainless steel hog rings.

8.5.3.2 TY304 stainless steel thread (0.011-in. (0.25-mm) diameter).

8.5.3.3 TY304 stainless steel staples.

8.5.3.4 Fiberglass thread (plain, polytetrafluoroethylene coated and wire inserted with monel or TY304 stainless steel, or both).

8.5.4 Installation Materials:

8.5.4.1 No. 18 gage copper lacing wire.

8.5.4.2 No. 18 gage soft or annealed TY304 stainless steel lacing wire.

8.5.4.3 No. 18 gage galvanized iron lacing wire.

8.5.4.4 TY304 stainless steel hog rings (particularly for installing thermal tape, refer also to Section 9).

8.6 Special Conditions:

8.6.1 Reuseable covers for machinery and equipment shall be fabricated from materials specified in Tables 14-17, in accordance with methods shown in Fig. 18 and configured to suit the specific application.

8.6.2 Unfired pressure vessels with butt welded inserts for which periodic radiographic inspection of the joint is required shall have removable reuseable covers installed over the insert. These covers shall extend 4 in. (100 mm) beyond the weld joint.

8.6.3 Removable covers shall not be used on systems insulated with elastomeric-foamed plastic insulation.
8.6.4 Services subject to frequent maintenance, such as reducing and regulating valves, shall be provided with easily removed and replaced tailored pads.

8.6.5 Removable blankets shall not be used on cold systems (below ambient) or on systems where a vapor barrier is required.

8.6.6 When stitching two or more covering or encapsulating materials together, stainless steel staples, hog rings, 0.011-in. (0.25-mm) diameter stitching wire, or fiberglass thread (plain or wire inserted) shall be used.

8.6.7 All construction details apply to removable blankets for flanges, valves, machinery and equipment, and other miscellaneous areas as determined by the specifier.

8.6.8 When installing removable blankets on valves, flanges, and various pieces of equipment, note that all void areas behind the insulation blanket are to be filled. The total required thickness of insulation shall not be achieved by including a loose wrap of fibrous glass felt or refractory fiber blanket as part of the required thickness.

9. Requirements for Thermal Insulating Tape

9.1 Thermal Insulating Tape—Is capable of being applied to pipe, sizes ¼ in. (8 mm) to ½ in. (20 mm), for temperatures between 125 and 150°F (52 and 66°C) using materials specified in Section 8 and to thicknesses specified in Table 14. For manufacturing and installation details, see Fig. 6.

9.2 Filler Materials for Thermal Insulating Tape —See 8.2.
9.3 Covering or Encapsulating Materials for Thermal Insulating Tape:

9.3.1 For surface temperatures below 220°F (105°C), the entire outside surface shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 3.

9.3.2 For surface temperatures 220 to 450°F (105 to 232°C), the entire outside surface shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9.

9.3.3 For surface temperatures above 450°F (232°C), the entire outside surface shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9, with an inner jacket of TY304 stainless steel wire mesh, 0.008-in. (0.21-mm) diameter, No. 60 density and crimped. Alternatively, the entire outside surface shall be encapsulated with fiberglass cloth, inserted with stainless steel wire reinforcement, in accordance with HH-P-31, Type I, Class 1.

9.4 Hardware and Accessory Items for Thermal Insulating Construction—See 8.5.
Coat all mating surfaces of insulation with vapor retarder compound MIL-C-22395.

Multiple layers shall have staggered joints.

Install insulation with all ends butted together.

Secure insulation in place with fibrous glass tape as necessary, three strips per section, overlapping a minimum of 50%.

Coat the outside surface of insulation with MIL-A 3316, Class 1 Adhesive coating in accordance with USCG 164-012 & 164.112. Cover with fibrous glass cloth lagging while still wet or lag with MIL-C-20079 fibrous glass cloth coated with re-wettable adhesive.

Coat outside surface of lagging with weather resistant insulation seal.

As an alternate to fibrous cloth lagging, metal lagging similar to that specified in Table 13 shall be used.

See FIG. 16 for bolting allowance in way of flanged, takedown joints.

FIG. 7 Installation of Cellular Glass Pipe Insulation (Specification C 552) in the Weather

9.5 Special Conditions—See 8.6.
10. Keywords

10.1 insulation; lagging; machinery insulation; marine; piping insulation; ship; shipboard insulation; thermal insulation; vessel
FIG. 9 Installation of Cellular (Foamed) Glass Insulation (Specification C 552) on Machinery and Equipment

Install sections of Cellular Glass Insulation (Specification C 552) with all joints staggered, tightly butted and coated with Adhesive Cement MIL-A-3316, Class I.

Secure insulation in place with wire, stainless steel bands or welded studs (where allowable), as necessary.

Coat outside surface of insulation with Adhesive Cement MIL-A-3316, Class I, and cover with fibrous glass cloth lagging while adhesive is still wet. Note: Is capable of being lagged with MIL-C-20079 fibrous glass cloth coated with re-wettable adhesive.

Coat outside surface of lagging with Vapor Retarder Compound MIL-C-19565, Type II when used for anti-sweat applications.

Machinery or equipment.

FIG. 9 Installation of Cellular (Foamed) Glass Insulation (Specification C 552) on Machinery and Equipment

FIG. 10 Installation of Elastomeric Foamed Plastic Insulation (MIL-P-15280 or EB 4013) on Machinery or Equipment

Machinery or Equipment

Install Elastomeric Foamed Plastic Insulation (MIL-P-15280, Form S or EB 4013) with all joints staggered, tightly butted and secured with MIL-A-24179 Adhesive.

Insulation is capable of being applied in 1/4-in. (6mm) thick minimum layers as necessary to build up the required thickness.

Application of a vapor retarder is not required on Elastomeric Foamed Plastic Insulation.

Elastomeric Foamed Plastic Insulation shall be coated with Adhesive MIL-A-3316, Class I and covered with glass cloth only in areas where it is subject to damage.

Note: Is capable of being lagged with MIL-C-20079 fibrous glass cloth coated with re-wettable adhesive.

FIG. 10 Installation of Elastomeric Foamed Plastic Insulation (MIL-P-15280 or EB 4013) on Machinery or Equipment
Install Polyimide Foam Insulation (C 1482, Type I) with all joints staggered, tightly butted, and secured with MIL-A-24179 Adhesive.

When used in the temperature range 100 to 400°F (38 to 204°C), shall be coated on outside surface with adhesive in accordance with MIL-A-3316 and cover with fibrous cloth lagging while the adhesive is still wet.

For anti-sweat treatments, use one of the following vapor retarder systems:

Coat outside surface of the insulation with MIL-A-3316 Adhesive and cover with fibrous glass cloth lagging while the adhesive is still wet. Paint with vapor retarder compound MIL-C-19565, Type II. Ensure that a continuous vapor retarder is achieved.

Aluminized polyester/aluminum foil shall be adhered to outer surface of the insulation using an adhesive conforming to the fire resistance requirements of MIL-A-3316. All joints and seams shall be sealed with 0.002 in. (0.0525 mm) aluminum pressure sensitive tape. Coat outside surfaces of aluminized polyester/aluminum foil with MIL-A-3316 Adhesive and cover with fibrous glass cloth lagging while the adhesive is still wet.

FIG. 11 Installation of Polyimide Foam Insulation (Specification C 1482, Type I) on Machinery and Equipment

FIG. 12 Installation of Mineral Fiber Blanket or Felt Insulation (Specification C 553) on Machinery or Equipment (400°F Max) (204°C)
FIG. 13 Installation of Thermal Fibrous Glass Felt Insulation (MIL-I-16411) or Refractory Fiber Blanket Insulation (Specification C 892) on Machinery and Equipment (126 to 1200°F) (52 to 649°C)

Machinery or equipment

Install Thermal Fibrous Glass Insulation Felt MIL-I-16411, Type II, or Refractory Filler Blanket Specification C 892. Insulation is applied in multiple layers to build up to the required thickness.

Secure insulation in place with wire, stainless steel bands, or welded studs (where allowable) as necessary.

Spread galvanized iron wire netting 1-in. (25 mm) mesh over insulation and secure with wire as necessary.

Apply a 1/2-in. (13 mm) thick coating of Finishing Cement Specification C 449 over wire mesh netting allowing 24 h drying time.

Coat the above with Adhesive Cement MIL-A-3316, Class I, and cover with fibrous glass cloth lagging while adhesive is still wet. Note: capable of being lagged with MIL-C-20079 fibrous glass cloth coated with rewetable adhesive.

FIG. 14 Installation of Thermal Insulation Block (Calcium Silicate) (Specification C 533) or Perlite (Specification C 610) on Machinery and Equipment

Machinery or equipment

Install Thermal Insulation Block (Calcium Silicate) Specification C 533 or Perlite Specification C 610.

Insulation shall be installed in two layers when the temperature is over 600 degrees F (316 degrees C). All joints shall be butted together and staggered.

Secure insulation in place with wire, stainless steel bands, or welded studs (where allowable) as necessary.

Spread galvanized iron wire netting 1-in. (25 mm) mesh over insulation and secure with wire as necessary.

Apply a 1/2-in. (13 mm) thick coating of Finishing Cement Specification C 449 over wire mesh netting allowing 24 h drying time.

Coat the above with Adhesive MIL-A-3316, Class I, and cover with fibrous glass cloth lagging while adhesive is still wet. Alternatively, is capable of being lagged with MIL-C-20079 rewetable fibrous glass cloth.

On vertical equipment, the bottom course of block insulation shall be supported by an angle iron run horizontally along the base. The horizontal leg of the angle shall be 1/2-in. (13 mm) less in length than the thickness of the insulation used.
FIG. 15 Installation of Removable Covers for Valves, Fittings, and Flanges

FIG. 16 Typical Removable Flange Cover in Which Flange Diameter is Larger Than the Outside Diameter of the Adjacent Pipe Covering
FIG. 17 Typical Removable Flange Cover in Which Flange Diameter is Smaller Than the Outside Diameter of the Adjacent Pipe Covering

Fill void with allowable felt or material insulation specified in Section 8 and secure in 0.060-in. (0.152mm) diameter Type 304 stainless steel wire mesh or FG-2-31, Type 1 wire reinforced fibrous glass cloth.

NOTE 1—For surface temperatures 450°F (232°C) and below.

NOTE 2—For surface temperatures above 450°F (232°C).

FIG. 18 Covering or Encapsulating Materials for Removable Blankets
FIG. 19 Typical Method of Lacing Removable Covers Using Lacing Rings
FIG. 20 Typical Method of Lacing Removable Covers Using Lacing Hooks

- 5/8-in. (16mm)
- 2-in. (50mm)

Wire - copper or galvanized iron

1-1/4-in. (32mm) typical

Lacing hook
Detail "D"

Lacing washer
Detail "C" (FIG 19)

See Detail "A" (FIG. 12) for securing lacing hooks to fibrous glass cloth

3/16-in. (5mm) RAD

1/2-in. (13mm)

3/8-in. (9.5mm)

3/16-in. (5mm) RAD

3/4-in. (19mm) RAD

Detail "D"
Typical lacing hook

FIG. 20 Typical Method of Lacing Removable Covers Using Lacing Hooks
FIG. 21 Alternate Method of Lacing Removable Covers Using Lacing Capstan Assembly Sets

FIG. 22 Alternate Method of Lacing Removable Covers Using Mechanical Hook Sets
S1. Supplemental Requirements and Exceptions to the Requirements of Practice F 683 for Ships of the U.S. Navy

S1.1 The U.S. Navy vessel insulation shall be installed in accordance with details in NAVSHIPS Drawings 804-5959214, 804-5959212, and Naval Ships Technical Manual, Chapter 635. Insulation details in this practice are for guidance only.

S1.1.1 Materials and their thicknesses approved for insulation and lagging for specific applications and temperature ranges are specified in Tables S1.1 and S1.2.

S1.2 Ceramic fiber insulation (Specification C 892) shall not be installed aboard vessel in accordance with COMNAVSEA-SYSCOM message R 131446Z NOV 86 ZYB, unless there presently are no NAVSEA-approved substitutes for a specific application. Where previously installed ceramic (refractory) fiber insulation or lagging materials containing ceramic (refractory) fibers are removed, restoration shall be with materials free of ceramic (refractory) fibers unless there are no NAVSEA-approved substitutes identified for a specific application.

S1.3 Cellular glass block and pipe thermal insulation (Specification C 552) shall not be used.

S1.4 Mineral fiber blanket and felt insulation (Specification C 553) shall not be used. For U.S. Navy applications, use MIL-I-2818 in accordance with Table S1.3. For passive fire protection applications, refer to NAVSEA Drawing No. 803-5184182.

S1.5 Mineral fiber preformed pipe insulation (Specification C 547) shall not be used. Insulate in accordance with Table S1.4.

S1.6 Fibrous glass pipe insulation shall be as specified in MIL-I-22344 and shall be used only on piping no greater than 1-in. NPS (25 mm) with maximum temperature limit of 370°F (188°C) in place of Specification C 547, Type 2. See Table S1.4 for restrictions on this material’s use.

S1.7 Calcium silicate block and thermal insulation shall be as specified in MIL-I-2819 and MIL-I-2781, respectively, in place of Specification C 533. Insulate in accordance with Tables S1.3 and S1.5.

S1.8 Mineral fiber block and board thermal insulation (Specification C 612) shall not be used.

S1.9 The requirements of 5.4, 5.7, and 5.10 do not apply to U.S. Navy vessels.

S1.10 Thermal insulating tape in accordance with Fig. 5 shall be used only on a temporary basis, such as repair of insulation while the vessel is at sea. Apply in accordance with Table S1.6.

S1.11 Cloth and tape lagging shall be painted after installation with one coat of nonflaming paint conforming to formula No. 124 of DoD-E-24607 or water base DoD-C-24596 or Navy formula 25A, if necessary for appearance. Unlagged insulation
conforming to EB Specification 4013 shall be sealed with one coat of Devoe and Raynolds “DEVLEX 601” or Ocean 9788, or water-base DoD-C-24596 or Navy formula 25A.

S1.12 The use of “other materials” (provided the requirements of this practice are satisfied) does not apply to U.S. Navy vessels. See 4.1, Footnote B to Table 1, Footnote A to Table 2, and Footnote B to Table 3.

S1.13 Footnote A to Table 1 and Table 3 does not apply to U.S. Navy vessels.

S1.14 MIL-P-15280 shall not be used on naval vessels; alternatives are as follows:

S1.14.1 For Temperature Ranges:

- **20 to 100°F (29 to 38°C)**
  - EB 4013
  - EB 4013 and DoD-I-24688, Type I and
    - MIL-I-22344 (see Tables S1.4 and S1.6)
  - EB 4013 and DoD-I-24688, Type I and
  - MIL-I-22344 (see Tables S1.4 and S1.6)

- **100 to 180°F (39 to 82°C)**
  - EB 4013
  - EB 4013 and DoD-I-24688, Type I and
    - MIL-I-22344 (see Tables S1.4 and S1.6)
  - EB 4013 and DoD-I-24688, Type I and
  - MIL-I-22344 (see Tables S1.4 and S1.6)

- **180 to 370°F (83 to 188°C)**
  - DoD-I-24688, Type I and MIL-I-22344
  - (see Tables S1.4 and S1.6)

S1.15 The U.S. Navy limits the use of polyimide foam to 400°F (204°C).
For repair or replacement of piping and machinery insulation, only the materials specified herein shall be used. Procedures for the repair and replacement of insulation are contained in Naval Ships Technical Manual (NSTM), Chapter 635.

S1.16 Special Conditions—The following special conditions supplement or modify the selection of materials or thicknesses specified, when applicable:

S1.16.1 The insulation thickness on soot blower piping between the root valve and the soot blower heads shall be reduced to one half that indicated for a system normally at the same temperature.

S1.16.2 For repair or replacement of piping and machinery insulation, only the materials specified herein shall be used.
S1.16.4 Adhesives containing halogenated solvents shall not be used for submarine applications.

S1.16.5 Insulation shall not be installed on 2 ft of pipe immediately upstream of thermostatic steam traps, complying with MIL-T-2118. A removable cover, consisting of two layers of glass cloth, shall be installed over the uninsulated pipe and the thermostatic trap.

S1.16.6 Small diameter hot piping, 1⁄2-in (15-mm) nominal pipe size (NPS) and under shall not be insulated when the operating temperatures are less than 125°F (52°C).

S1.16.7 Shielding on uninsulated hot pipes shall be provided only where such pipes are readily accessible to contact with personnel.

S1.16.8 MIL-I-2781 shall be used in “high traffic” areas on hot piping whose design temperature is greater than 180°F (82°C). “High traffic” areas are those areas in which the installed insulation and lagging are subject to wear and damage during routine operations. Alternatively, DoD-I-24688 is capable of being used on hot piping in “high traffic” areas that are in a vertical orientation.

### TABLE S1.4 Thickness of Insulation Conforming to EB Specification 4013, DoD-I-24688, and MIL-I-22344, for Hot Piping

<table>
<thead>
<tr>
<th>Maximum Operating Temperature Range, °F (°C)</th>
<th>Specification</th>
<th>Nominal Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 to 180 (52 to 82)</td>
<td>MIL-I-22344&lt;sup&gt;A&lt;/sup&gt;,&lt;sup&gt;B&lt;/sup&gt; EB Specification 4013 DoD-I-24688, Type I MIL-I-22344&lt;sup&gt;A&lt;/sup&gt;,&lt;sup&gt;B&lt;/sup&gt;</td>
<td>1⁄2 (13)</td>
</tr>
<tr>
<td>181 to 250 (83 to 121)</td>
<td>DoD-I-24688, Type I MIL-I-22344&lt;sup&gt;A&lt;/sup&gt;,&lt;sup&gt;B&lt;/sup&gt;</td>
<td>3⁄4 (19)</td>
</tr>
<tr>
<td>251 to 300 (122 to 149)</td>
<td>DoD-I-24688, Type I MIL-I-22344&lt;sup&gt;A&lt;/sup&gt;,&lt;sup&gt;B&lt;/sup&gt;</td>
<td>1 (25)</td>
</tr>
<tr>
<td>301 to 350 (150 to 177)</td>
<td>DoD-I-24688, Type I MIL-I-22344&lt;sup&gt;A&lt;/sup&gt;,&lt;sup&gt;B&lt;/sup&gt;</td>
<td>1 (25)</td>
</tr>
<tr>
<td>351 to 400 (178 to 204)</td>
<td>DoD-I-24688, Type I</td>
<td>1 1⁄2 (38)</td>
</tr>
</tbody>
</table>

<sup>A</sup> Shall only install on piping no greater than 1 in. (25 mm) NPS (for surface ships only).

<sup>B</sup> Shall not be installed in designated “high traffic” areas unless in a vertical orientation.

### TABLE S1.5 Thickness of Insulation for Hot Piping Conforming to MIL-I-2781

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in. (mm)</th>
<th>Temperature Range, °F (°C)</th>
<th>Nominal Thickness, Total&lt;sup&gt;A&lt;/sup&gt; in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄2 , 1 1⁄2 (13, 38)</td>
<td>125–388 (53–198)</td>
<td>1 1⁄2 (38)</td>
</tr>
<tr>
<td></td>
<td>389–750 (199–399)</td>
<td>2 1⁄2 (63)</td>
</tr>
<tr>
<td></td>
<td>751–950 (400–510)</td>
<td>3 (76)</td>
</tr>
<tr>
<td></td>
<td>951–1050 (511–566)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>2, 2 1⁄2 (51, 63)</td>
<td>125–338 (52–170)</td>
<td>1 1⁄2 (38)</td>
</tr>
<tr>
<td></td>
<td>339–388 (171–198)</td>
<td>2 (51)</td>
</tr>
<tr>
<td></td>
<td>389–900 (199–482)</td>
<td>3 (76)</td>
</tr>
<tr>
<td></td>
<td>901–1050 (483–566)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>3–4 1⁄2 (76–114)</td>
<td>125–338 (52–170)</td>
<td>1 1⁄2 (38)</td>
</tr>
<tr>
<td></td>
<td>339–388 (171–198)</td>
<td>2 1⁄2 (63)</td>
</tr>
<tr>
<td></td>
<td>389–500 (199–260)</td>
<td>3 (76)</td>
</tr>
<tr>
<td></td>
<td>501–900 (261–482)</td>
<td>3 1⁄2 (89)</td>
</tr>
<tr>
<td></td>
<td>901–950 (483–510)</td>
<td>4 (102)</td>
</tr>
<tr>
<td></td>
<td>951–1050 (511–566)</td>
<td>4 1⁄2 (114)</td>
</tr>
<tr>
<td>5, 6, 7 (127, 152, 178)</td>
<td>125–338 (52–170)</td>
<td>1 1⁄2 (38)</td>
</tr>
<tr>
<td></td>
<td>339–388 (171–198)</td>
<td>2 1⁄2 (63)</td>
</tr>
<tr>
<td></td>
<td>389–750 (199–398)</td>
<td>3 1⁄2 (89)</td>
</tr>
<tr>
<td></td>
<td>751–900 (399–482)</td>
<td>4 (102)</td>
</tr>
<tr>
<td></td>
<td>901–950 (483–510)</td>
<td>4 1⁄2 (114)</td>
</tr>
<tr>
<td></td>
<td>951–1050 (511–566)</td>
<td>5 (127)</td>
</tr>
<tr>
<td>8 (203) or larger</td>
<td>125–338 (52–170)</td>
<td>1 1⁄2 (38)</td>
</tr>
<tr>
<td></td>
<td>339–388 (171–198)</td>
<td>2 1⁄2 (63)</td>
</tr>
<tr>
<td></td>
<td>389–500 (199–260)</td>
<td>3 1⁄2 (89)</td>
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<tr>
<td></td>
<td>501–750 (261–398)</td>
<td>4 (102)</td>
</tr>
<tr>
<td></td>
<td>751–900 (399–482)</td>
<td>4 1⁄2 (114)</td>
</tr>
<tr>
<td></td>
<td>901–950 (483–510)</td>
<td>5 (127)</td>
</tr>
<tr>
<td></td>
<td>951–1050 (511–566)</td>
<td>6 (152)</td>
</tr>
</tbody>
</table>

<sup>A</sup> Does not include finishing cement.

<sup>B</sup> Wherever possible, double layers shall be used where temperatures exceed 600°F (316°C). Double layers are capable of being used at temperatures below 316°F.
S1.16.9 These insulation materials shall not be used on austenitic stainless steel components without a corrosion study.

S1.17 Adhesives:

S1.17.1 Adhesives conforming to MIL-A-3316 shall be used for fastening fibrous glass cloth and tape lagging only in inaccessible areas or where rewettable lagging cannot be applied. The MIL-C-20079, Type I, Class 6 and 8 fibrous glass cloth with pre-applied rewettable adhesive manufactured by BGF Industries, 3802 Robert Porcher Way, Greensboro, NC 27410 or Alpha Maritex Style 2014/9485 RW manufactured by Alpha Associates is an alternative and preferred system to the fibrous glass cloth adhered with MIL-A-3316 adhesive for lagging. However, it shall not be used for areas subject to live steam or dampness.

S1.17.2 Rubatex R373 and Armacell 520 are the only adhesives to secure EB Specification 4013 insulation to itself and to metals for surface ships and submarines.

S1.17.3 Sodium silicate solution, Specification D 3400, shall be used as an adhesive for joining segments of calcium silicate preformed pipe insulation in accordance with MIL-I-2781.

S1.18 Finishing/Insulation Cements—Where finishing and insulating cements are specified, any of the following materials are acceptable. Before use, material compatibility with the proposed application will be verified.

S1.18.1 Hydraulic-setting mineral fiber finishing and insulating cement in accordance with Specification C 449/C 449M.

S1.19 Metal Lagging—Where metal lagging is required, any of the following materials are acceptable, except for uptake applications (see S1.25.4.1):

<table>
<thead>
<tr>
<th>Sheet Material</th>
<th>Specification</th>
<th>Nominal Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-dipped galvanized steel</td>
<td>ASTM A 526/A 526M</td>
<td>0.014 (0.356)</td>
</tr>
<tr>
<td>Aluminum</td>
<td>ASTM B 209/B 209M, 6061</td>
<td>0.030 (0.762)</td>
</tr>
<tr>
<td>Corrosion-resistant steel</td>
<td>ASTM A 167, Type 304</td>
<td>0.014 (0.356)</td>
</tr>
</tbody>
</table>

S1.20 Fasteners—Insulation shall be held in place by suitable wire or flat metal bands. The welding of fasteners to machinery, piping, pressure vessels, or other related equipment is prohibited. Where fasteners are necessary, they shall be attached during manufacture (before heat treatment, stress relief, and testing) by a NAVSEA-approved procedure.

S1.21 Hot-Surface Insulation Covers—To ensure that the pipe covering will not interfere with the servicing of a takedown joint where a reusable cover is installed, the permanent insulation shall stop short of the takedown joint and a short removable and reusable section of insulation shall be installed between the permanent insulation and the takedown joint. The insulation joint formed by the permanent and reusable sections shall be square, or at an angle of 45°. The reusable section shall fit tightly at the interfacing joint without gaps and shall be held in place with removable pins, clips, wire, or bands to maintain a tight joint.

S1.22 Construction—For sizes larger than 2-in. (50-mm) NPS, valve bonnets and valves having takedown joints at the ends shall be fitted with reusable covers such that the bonnet joint is capable of being removed independently of the valve covering. Valves, not greater than or equal to 2-in. NPS, shall be fitted with separate covers as indicated previously, or covers of a one-piece design such that they shall be wrapped around the entire valve body and clipped or otherwise secured just below the packing gland on the valve stem. The packing gland shall remain visible.

S1.23 Fabrication, Piping Components—For piping components except as otherwise specified, any one of the following methods of fabrication is acceptable.

S1.23.1 Covers for Piping Components—Covers that are exposed to temperatures under 450°F (232°C) are capable of being made in two half sections, using fibrous glass felt in accordance with MIL-I-16411 enclosed in fibrous glass fabric conforming to
Covers Formed from Block Insulation—

Covers shall be made of segments of block insulation or preformed pipe insulation, having the same thickness as that on the adjacent piping. Blocks shall be securely wired to frames of 1/2-in. square mesh, 300 Series stainless steel wire with a diameter of 0.0403 in. (1.024 mm). Wire mesh frames inside and outside of blocks shall have ends bent over and joints secured with Number 18 gage black annealed iron wire woven through the mesh. High-temperature cement in accordance with MIL-C-2861 shall be troweled smoothly over all surfaces of the wire mesh. Fibrous glass felt in accordance with MIL-I-16411 shall be used to build up covers when the flange diameter is larger than the outside diameter of the adjacent pipe covering. Covers shall be tightly and smoothly lagged to envelop the outside and ends, using fibrous glass cloth conforming to MIL-C-20079, Type I, Class 9. Lagging shall be either cemented or sewn on, except the ends of covers, which shall always be sewn. Where double-layer insulation is used, the two sections of the cover shall be fitted together with a scarfed joint. Such joints shall be straight and true to reduce heat loss. Bands; eyelets or locks of galvanized steel; or lacing with hooks, rings, washers, and wire shall be used to secure the covers.

Preformed Covers—Preformed fibrous glass or polyimide foam, DoD-I-24688, Type I valve or fitting covers shall be used when temperatures are in the 125 to 400°F (52 to 204°C) range. These shall be of the same thickness as the adjacent pipe covering. Such covers, when used, shall be lagger independently of the pipe covering and in a manner that will facilitate removal and replacement.

Fabrication, Machinery, and Equipment—Covers shall be made of segments of block insulation or preformed pipe insulation, having the same thickness as that on the adjacent piping. Blocks shall be securely wired to frames of 1/2-in. square mesh, 300 Series stainless steel wire with a diameter of 0.0403 in. (1.024 mm). Wire mesh frames inside and outside of blocks shall have ends bent over and joints secured with Number 18 gage black annealed iron wire woven through the mesh. High-temperature cement in accordance with MIL-C-2861 shall be troweled smoothly over all surfaces of the wire mesh. Fibrous glass felt in accordance with MIL-I-16411 shall be used to build up covers when the flange diameter is larger than the outside diameter of the adjacent pipe covering. Covers shall be tightly and smoothly lagged to envelop the outside and ends, using fibrous glass cloth conforming to MIL-C-20079, Type I, Class 9. Lagging shall be either cemented or sewn on, except the ends of covers, which shall always be sewn. Where double-layer insulation is used, the two sections of the cover shall be fitted together with a scarfed joint. Such joints shall be straight and true to reduce heat loss. Bands; eyelets or locks of galvanized steel; or lacing with hooks, rings, washers, and wire shall be used to secure the covers.

Heat-Surface Insulation:

Pipe and Tubing—Each layer of molded insulation shall be installed with joints butted together. Where two layers are

*MIL-C-20079, Type I, Class 9. Alternatively, silicone rubber-coated, or silicone rubber/aluminized glass fabric is capable of being substituted for plain fibrous glass fabric for the cover material. Covers that are exposed to temperatures of 450°F (232°C) and over shall have a 0.008-in. (0.203-mm) diameter knitted stainless steel wire mesh sewn on to the fibrous glass cloth on the inside (hot) surface and on the ends. Alternatively, the inside surface and ends of pads shall be fabricated of wire-reinforced fibrous glass cloth conforming to HH-P-3 I, Type I, Class I. Each half cover shall be sewn and quilted with polytetrafluoroethylene (PTFE) coated fibrous glass yarn conforming to MIL-C-20079, Type III, Classes 3, 4, or 6 for hand sewing or PTFE-coated fibrous glass sewing thread (fully sintered), Type III, Class 3, 5, or 6 for machine sewing. The covers are also capable of being fastened by mechanical stapling with galvanized or stainless steel staples in a manner to provide uniform thickness, strength, and rigidity.

*S1.23.1.1 Wire Mesh—Knitted wire mesh shall be of 304 annealed stainless steel. The wire shall be 0.008-in. diameter. The mesh shall consist of 71/2 ± 1/2 in. (188 ± 13 mm) courses per inch equal spacing and 10 ± 1 wales per inch equal (3.9 ± 0.5 wales per cm) spacing. The mesh shall be furnished in 30 ± 1/2 in. (750 mm ± 13 mm) flattened tubular form and shall be crimped 0.125 to 0.150 in. (3.18 to 3.81 mm) deep by 3/4 in. (7.94 mm) crimp to crimp.

S1.23.2 Preformed Covers—Preformed fibrous glass or polyimide foam, DoD-I-24688, Type I valve or fitting covers shall be used when temperatures are in the 125 to 400°F (52 to 204°C) range. These shall be of the same thickness as the adjacent pipe covering. Such covers, when used, shall be lagger independently of the pipe covering and in a manner that will facilitate removal and replacement.

S1.23.3 Block and Preformed Insulation—Covers shall be made of segments of block insulation or preformed pipe insulation, having the same thickness as that on the adjacent piping. Blocks shall be securely wired to frames of 1/2-in. square mesh, 300 Series stainless steel wire with a diameter of 0.0403 in. (1.024 mm). Wire mesh frames inside and outside of blocks shall have ends bent over and joints secured with Number 18 gage black annealed iron wire woven through the mesh. High-temperature cement in accordance with MIL-C-2861 shall be troweled smoothly over all surfaces of the wire mesh. Fibrous glass felt in accordance with MIL-I-16411 shall be used to build up covers when the flange diameter is larger than the outside diameter of the adjacent pipe covering. Covers shall be tightly and smoothly lagged to envelop the outside and ends, using fibrous glass cloth conforming to MIL-C-20079, Type I, Class 9. Lagging shall be either cemented or sewn on, except the ends of covers, which shall always be sewn. Where double-layer insulation is used, the two sections of the cover shall be fitted together with a scarfed joint. Such joints shall be straight and true to reduce heat loss. Bands; eyelets or locks of galvanized steel; or lacing with hooks, rings, washers, and wire shall be used to secure the covers.

S1.23.4 Felt—When installing the preceding covers, spaces between inner surfaces of covers for flanges and other irregular surfaces shall be filled with pieces of fibrous glass insulation felt in accordance with MIL-I-16411. Felt shall be packed loosely enough to preserve air cell structure and tightly enough to prevent air circulation.

S1.23.5 Mineral Fiber (Rock/Slag)—Preformed mineral fiber (rock/slag) insulation with a hard fibrous glass cover (CADAFIT 1200°F [649°C]) or the equivalent is capable of being used as applicable. For the appropriate thickness of CADAFIT 1200°F or the equivalent mineral fiber (rock/slag) insulation, refer to the thicknesses shown in Table S1.2 at the appropriate temperature range.

S1.24 Fabrication, Machinery, and Equipment—For reusable covers for machinery and equipment, either of the following methods of fabrication is acceptable.

S1.24.1 Machinery and Equipment Covers—Covers similar to fibrous glass felt in accordance with MIL-I-16411 described for piping components (see S1.23.1).

S1.24.2 Covers Formed from Block Insulation—Covers made in sections formed of insulating block held together with wire and adhesive cement, covered with 1/2-in. (13-mm) thickness of finishing cement, Specification C 449/C 449M and lagged. Lacing with hooks, rings, washers, and wire or brass snap fasteners shall be used to secure the covers.

S1.24.3 Semiremovable Turbine Covers—Semiremovable turbine casing flange covers are capable of being installed as an alternative for removable covers previously specified. The permanent insulation shall be run to the casing flange, allowing for bolt removal space. The flange and bolts shall be covered with (1) fibrous glass cloth in accordance with MIL-C-20079, Type I; (2) wire inserted fibrous glass cloth in accordance with HH-P-3 I, Type I, Class 1; or (3) knitted wire mesh, as required by operating temperature. The chosen cover shall be secured to the bolts with wire. The flange shall then be insulated with fibrous glass felt in accordance with MIL-I-16411, mineral wool felt in accordance with MIL-I-2818, or insulation block in accordance with MIL-I-2819, Class 2 to the required thickness and shape. The insulation shall then be lagged with fibrous glass cloth, which shall be carried over the outer edge of the permanent insulation and secured with adhesive. The semiremovable cover shall then be sealed with adhesive in accordance with MIL-A-3316, Class 1, and painted.

S1.25 Hot-Surface Insulation:

S1.25.1 Pipe and Tubing—Each layer of molded insulation shall be installed with joints butted together. Where two layers are
used, joints shall be staggered. Not less than three fastenings shall be used to secure each 3-ft section of insulation. Fastening shall be Number 18 gage minimum (0.049-in. [1.245-mm] diameter) annealed black iron or 300 Series stainless steel wire with a diameter of 0.0403-in. (1.024-mm) wire or flat steel bands. Except as otherwise specified, lagging shall be installed over the insulation.

S1.25.1.1 Preformed Polyimide Pipe Covers—Preformed polyimide pipe covering conforming to DoD-I-24688, Type I, shall be lagged or prelagged with MIL-C-20079 fibrous glass cloth facing on piping systems whose design temperature is between 100 and 400°F (38 to 204°C).

S1.25.1.2 Soot Blower Piping—The installation of soot blower piping insulation shall be in accordance with Drawing 804-841336.

S1.25.2 Piping Components—Valves, fittings, and accessories with welded and brazed fittings including unions, shall be insulated and lagged similarly to adjacent piping.

S1.25.2.1 Block, Felt, Molded Insulating Materials—Block or felt insulating materials, or molded pipe insulation secured with hot-dipped galvanized iron or steel wire, shall be used. When insulating felts are used, the inner layer shall be fibrous glass felt conforming to MIL-I-16411. Galvanized iron or steel wire netting, Number 18 gage minimum (0.049-in. [1.245-mm] diameter), shall be spread over the insulating material and secured with wire. Insulating cement shall be used to fill crevices, smooth surfaces, and completely cover the wire netting. A ½-in. (13-mm) thickness of finishing cement shall then be applied. Alternatively, wire netting shall be omitted where the size of the installation does not require netting to hold the insulation cement in place during the installation process. For these installations, glass cloth shall be installed over the previously finished insulation material without the intermediate layer of wire mesh. Insulating material shall be the same thickness as that on adjacent piping.

S1.25.2.2 Reusable Covers—Reusable covers shall be fitted where required.

S1.25.3 Machinery and Equipment—For machinery and equipment, block, felt, or blanket insulating materials of the required thickness shall be secured with “GB” (galvanized before weaving) iron wire, “GB” galvanized iron wire netting, 1-in. (25-mm) mesh and 20- to 22-gage minimum (0.88- to 0.73-mm diameter), shall be spread over the surface and secured by wire. Insulating cement shall be used to fill crevices, smooth surfaces, and completely cover the wire netting. Use stainless steel wire netting, Type 304 (20 gage) for temperatures above 370°F (188°C).

S1.25.3.1 Use of Finishing Cement—When no insulating cement has been specified, a ½-in. (13-mm) thickness of finishing cement shall be applied.

S1.25.3.2 Insulating Cement—When insulating cement has been specified, it shall be applied in successive layers, ½ to 1 in. (13 to 25 mm) in thickness, until the total thickness specified has been reached. Wire netting, similar to that used for covering the insulating materials shall be installed between layers. A ½-in. (13-mm) thickness of finishing cement shall be applied over the last layer of insulating cement.

S1.25.3.3 Lagging—Lagging shall be installed over finishing cement. Reusable covers shall be installed where required.

S1.25.3.4 Fastenings—Clips, hooks, or other fastenings for securing insulation or lagging shall not be brazed or welded to nonferrous parts of distilling plants or deaerating feed tanks.

S1.25.4 Boiler Uptakes—Boiler uptake thermal insulation shall be insulated with either mineral wool felt in accordance with MIL-I-2818 or fibrous glass felt in accordance with MIL-I-16411. If acoustic absorptive treatment is found to be necessary to decrease the noise level, the insulation thickness shall be increased accordingly.

S1.25.4.1 Metal Lagging—Metal lagging for uptakes shall be galvanized sheet steel conforming to Specification A 653/A 653M Coating Designation G-115, not less than ½ in. (0.794 mm) thick.

S1.25.4.2 Exceptions—Insulation and lagging is not required on uptakes above the weather deck, except where the transfer of heat to spaces adjacent to the uptake area is objectionable.

S1.25.5 Unfired Pressure Vessels—Unfired pressure vessels, including catapult wet accumulators, shall be covered with block insulation, MIL-I-2819, or fibrous glass felt in accordance with MIL-I-16411. Insulation shall be held in place with 18-gage galvanized wire spaced on approximately 3-in. (75-mm) centers or steel strapping spaced on not greater than 9-in (225-mm) centers. Insulation shall be covered with ½-in. (13-mm) finishing cement in accordance with Specification C 449/C 449M, lagged with fibrous glass cloth in accordance with MIL-C-20079, Type I and painted as in accordance with S1.11. Insulation in the way of vessel supports shall be metal faced to prevent insulation from wedging between the vessel and its support.

S1.25.5.1 Removable and Reusable Covers—Removable and reusable covers shall be installed over butt-welded shell inserts for which periodic radiographic inspection of the joint is required. These covers shall extend 4 in. (100 mm) beyond the welded joint.

S1.25.6 Outer Boiler Casing—If insulation is specified by pertinent ship’s specification or contract, insulation block in accordance with MIL-I-2819, Class 2, shall be secured to casing by wire netting (20- to 22-gage [0.88- to 0.73-mm diameter]), GB/galvanized, 1-in. hexangle wire mesh laced to welded notched studs on the boiler casing. Finishing cement, Specification C 449/C 449M, shall be used to fill crevices, smooth surfaces, and completely cover the netting to ½-in. (13-mm) thickness. Glass cloth conforming to MIL-C-20079, Type I, class as applicable, shall be used to lag the insulation and shall be painted in accordance with S1.11.

S1.26 Antisweat Insulation (Cold and Chilled Water Service)—Antisweat piping insulation shall consist of preformed pipe insulation conforming to EB Specification 4013. Thickness shall be ⅝ in. on all pipe sizes, except in air-conditioned spaces, where thickness shall be ½ in. (13 mm). On large pipe sizes, EB Specification 4013 insulation sheet form shall be applied in not less than
S1.27 Refrigerant Insulation—Insulation in accordance with EB Specification 4013 shall be applied in not less than \( \frac{1}{4} \)-in. (6-mm) thickness layers as necessary to build up the required thickness (tubular or sheet, as applicable). Longitudinal and butt joints shall be staggered. Joints shall be sealed using adhesive conforming to MIL-A-24179. Glass cloth lagging shall be applied over insulation in high traffic areas to protect against damage. Rewettable lagging in accordance with MIL-C-20079, Type I, Class 6 or 8, and manufactured by BGF Industries or Alpha Maritex Style 2014/9485 RW manufactured by Alpha Associates are the laggings qualified for fire performance for use with insulation conforming to EB Specification 4013.

S1.28 Weather Deck Hot Piping Insulation—Sectional preformed calcium silicate (MIL-I-2781) insulation for piping exposed to the weather shall be installed as follows:

S1.28.1 Preliminary Preparation Piping:
S1.28.1.1 All surfaces shall be clean, dry, and free of scale and grease.
S1.28.1.2 Fittings, valves, flanges, pipe supporting clamp, and not less than 3 in. (75 mm) of adjacent pipe shall be painted as follows: Apply one coat pretreatment formula 117 in accordance with DoD-C-15328 to a dry film thickness (DFT) of not greater than 0.0005 in. (0.0127 mm) (0.5 mil). After this coat dries, apply two coats of aluminum paint made by mixing 2 lb of aluminum paste in accordance with Specification D 962, with each gallon of phenolic varnish for temperatures up to 300°F (149°C). For temperatures above 300°F, apply two coats of paint conforming to TT-P-28.

S1.28.2 Installation on Pipes:
S1.28.2.1 Longitudinal joints on horizontal piping shall be on the top and bottom of the pipe; joints shall be staggered.
S1.28.2.2 Insulation shall be secured tightly to pipe with \( \frac{1}{2} \)-in. (13-mm) wide 22-gage galvanized steel bands or 18-gage galvanized iron wire on 9-in. (225-mm) centers.
S1.28.2.3 Fill all joints and voids in the insulation with high-temperature cement in accordance with MIL-C-2861. Wrap tightly with one layer of fibrous glass lagging cloth in accordance with MIL-C-20079, Type I, using adhesive in accordance with MIL-A-3316, Class 1. After the adhesive has dried, the lagging shall be coated with two brush coats of end sealing compound in accordance with MIL-C-22395.
S1.28.2.4 Where insulation is stopped off on the piping, the preformed insulation shall be tapered. The exposed surface and 3 in. (75 mm) of pipe shall be coated with sealing compound in accordance with MIL-C-22395. Fibrous glass lagging cloth, in accordance with MIL-C-20079, Type I, class as applicable, tailored to fit over the tapered insulation and exposed pipe shall be applied while the end sealing compound is still tacky. The lagging shall be attached to the insulation using adhesive in accordance with MIL-A-3316, and to the pipe with a \( \frac{1}{2} \)-in. (13-mm) wide 22-gage galvanized steel band.

S1.28.3 Installation on Fittings, Flanges, and Valves:
S1.28.3.1 Before applying flange insulation, weather deck piping shall be tested and secured in the following manner: After specified tests are completed, weather deck piping shall be subjected to alternate periods of full operating pressure, allowing pipe to come to maximum temperature, and then to zero gage pressure allowing pipe to come to ambient temperature. These cycles shall be repeated a sufficient number of times, with tightening and adjusting flanges where necessary, until no leaks are detected.
S1.28.3.2 Fittings, flanges, and valve covers shall be ship fabricated from sections of molded pipe covering block cemented together with adhesive in accordance with Specification D 3400.
S1.28.3.3 Permanent covers for fittings and valves shall be fitted snugly to fittings and adjacent pipe covering using the same material and methods as outlined for pipe covering. Voids between insulation and fitting shall be filled with tightly packed fibrous glass felt in accordance with MIL-I-16411. Permanent covers shall be lagged and coated in the same manner as the adjacent piping insulation.
S1.28.3.4 Where specified, rigid-type removable flange covers shall extend over the adjacent pipe covering \( \frac{1}{2} \) times the thickness of the insulation. The two halves of the cover shall be coated and lagged separately, using the same materials and procedure as outlined for weather deck hot pipe covering. The galvanized steel bands used to secure the two halves together and to the adjacent pipe covering shall be applied over the lagging and then coated with the end sealing compound in accordance with MIL-C-22395.

S1.28.4 Installation Around Supports and Hangers—Remove only enough insulation from butt edges to provide a snug fit around support brackets or hanger rods. Fill voids between insulation and support with tightly packed fibrous glass felt in accordance with MIL-I-16411 to within \( \frac{1}{4} \) in. (6 mm) from insulation surface. Fill the remainder of space with sealing compound, in accordance with MIL-C-22395, overlapping generously both the support member and the adjacent insulation. Lag and coat with the same method and materials as adjacent piping.

S1.29 Metal Lagging—Metal lagging, where required, shall be installed with lap joints, secured with hardened self-tapping screws (not to be used for below ambient conditions) or metal bands. Joints shall be arranged in a manner which will facilitate run off of impinging liquids.
APPENDIX
(Nonmandatory Information)

XI. RATIONALE

X1.1 This Appendix provides general background information for this practice which is an adaptation of the former MIL STD 769, Thermal Insulation Requirements for Machinery and Piping. The intent of this practice is to provide general guidance describing commercial ship thermal insulation requirements in the main body and military ship requirements in the Supplementary Requirements section. Note that some military specifications and standards are referenced in the main body since there are no approved ASTM equivalents at this time. As ASTM equivalents for these military documents are approved, they will be substituted in the main body, and eventually, the military documents will be purged from this ASTM Practice.

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Standard Practice for
Selecting Bolting Lengths for Piping System Flanged Joints

This standard is issued under the fixed designation F 704; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers bolt and stud bolt lengths, quantities, and thread series for pipe to pipe and pipe to valve flanged joints (Note 1) in the nominal pipe size ranges of ½- through 48-in. (12.7- through 1219-mm) diameter and pressure range of 125 through 2500 psi (0.8 through 17 236 kPa).

Note 1—This is applicable when flange of valve has the same thickness as mating flange.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ANSI Standards:

B1.1 Unified Screw Threads

B16.1 Cast Iron Pipe Flanges and Flanged Fittings (25, 125, 250, and 800 lb)

B16.5 Steel Pipe Flanges and Flanged Fittings (150, 300, 400, 600, 900, 1500, and 2500 lb Including Reference to Valves)

B16.24 Bronze Flanges and Flanged Fittings (150 and 300 lb)

B18.2.1 Square and Hex Bolts and Screws

B18.2.2 Square and Hex Nuts

2.2 Other Standard:

MSS SP-44 Steel Pipe Flanges

1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


2 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

3 Available from Manufacturer’s Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.

3. Bolting Criteria

3.1 Bolt and stud bolt lengths are computed using the following (see Annex A1):

3.1.1 Includes maximum nut thickness in accordance with ANSI B18.2.2.

3.1.2 Does not include washer thickness.

3.1.3 Does not include bolt or stud bolt point height.

3.1.4 Includes allowance for up to ⅛-in. (3.2-mm) thick gaskets, except butterfly valves.

3.1.5 Includes ¼-in. (6.3-mm) raised face in addition to flange thickness listed in tables for flanges rated at 400 psi (2.8 kPa) and above.

3.1.6 Includes use of heavy hex nut and bolt design.

3.1.7 Includes plus tolerance for flange thickness in accordance with ANSI B16.5.

3.2 All bolts and stud bolts have threads in accordance with ANSI B1.1. Class 2A dimensioning and nuts Class 2B.

3.3 The material requirements for bolts, stud bolts, and nuts are obtained from the material specifications of individual system diagrams.

3.4 Alloy steel bolting 1-in. (25.4-mm) nominal diameter and smaller and all carbon steel bolting has threads of the UNC Series; alloy steel bolting above 1-in. nominal diameter has threads of the 8-UN Series.

3.5 For detailed descriptions of flange bolting assemblies, butterfly valve bolting assemblies, and tapped lug-type butterfly valve bolting assemblies, refer to Figs. 1–7.

4. List of Tables

4.1 The tables are arranged in the following sequence:

150-lb Steel Flanged Joints

300-lb Steel Flanged Joints

400-lb Steel Flanged Joints

600-lb Steel Flanged Joints

900-lb Steel Flanged Joints

1500-lb Steel Flanged Joints

2500-lb Steel Flanged Joints

150-lb Bronze Flanged Joints

300-lb Bronze Flanged Joints

150-lb Steel Flat Face to 150-lb Bronze Flanged Joints

300-lb Steel Flat Face to 300-lb Bronze Flanged Joints

Table 1

Table 2

Table 3

Table 4

Table 5

Table 6

Table 7

Table 8

Table 9

Table 10

Table 11
### Table 1: Bolt Lengths for 150-lb Steel Flanged Joints to ANSI B16.5 and MSS SP-44 (see Fig. 1 and Fig. 2)

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*<sup>A</sup>1 in. = 25.4 mm.

### Table 2: Bolt Lengths for 300-lb Steel Flanged Joints to ANSI B16.5 (see Fig. 1 and Fig. 2)

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*<sup>A</sup>1 in. = 25.4 mm.
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A 1 in. = 25.4 mm.

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### TABLE 3 Bolting Lengths for 400-lb Steel Flanged Joints to ANSI B16.5 (see Fig. 3 and Fig. 4)

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A 1 in. = 25.4 mm.

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### TABLE 4 Bolting Lengths for 600-lb Steel Flanged Joints to ANSI B16.5 (see Fig. 3 and Fig. 4)

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A 1 in. = 25.4 mm.
### TABLE 5 Bolting Lengths for 900-lb Steel Flanged Joints to ANSI B16.5 (see Fig. 3 and Fig. 4)

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A 1 in. = 25.4 mm.

### TABLE 6 Bolting Lengths for 1500-lb Steel Flanged Joints to ANSI B16.5 (see Fig. 3 and Fig. 4)

<table>
<thead>
<tr>
<th>Nominal Pipe Size,</th>
<th>Bolt Diameter,</th>
<th>Quantity per Joint</th>
<th>Flange Thickness,</th>
<th>Bolt Stud</th>
<th>Bolt Length</th>
<th>Stud Bolt Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in. A</td>
<td></td>
<td>in. A</td>
<td>Bolt Thread</td>
<td>Steel, in. A</td>
<td>Steel, in. A</td>
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<tr>
<td>1/2</td>
<td>3/4</td>
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<td>7/8</td>
<td>7/4-10 UNC-2A</td>
<td>not used</td>
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<td>7/4-10 UNC-2A</td>
<td>not used</td>
<td>4 1/4</td>
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<td>7/8</td>
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<td>7/4-9 UNC-2A</td>
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<td>1 1/4</td>
<td>7/4-9 UNC-2A</td>
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<td>1 1/4-8 UN-2A</td>
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<td>2 1/4</td>
<td>1 1/4-8 UN-2A</td>
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<td>1 1/4-8 UN-2A</td>
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A 1 in. = 25.4 mm.

### TABLE 7 Bolting Lengths for 2500-lb Steel Flanged Joints to ANSI B16.5 (see Fig. 3 and Fig. 4)

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<th>Nominal Pipe Size,</th>
<th>Bolt Diameter,</th>
<th>Quantity per Joint</th>
<th>Flange Thickness,</th>
<th>Bolt Stud</th>
<th>Bolt Length</th>
<th>Stud Bolt Length</th>
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<td>in. A</td>
<td>Bolt Thread</td>
<td>Steel, in. A</td>
<td>Steel, in. A</td>
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</tr>
<tr>
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<td>4</td>
<td>1 3/4</td>
<td>3/4-10 UNC-2A</td>
<td>not used</td>
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</tr>
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<td>7/8</td>
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<td>7/4-9 UNC-2A</td>
<td>not used</td>
<td>6 1/4</td>
</tr>
<tr>
<td>1 1/4</td>
<td>7/8</td>
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<td>7/4-9 UNC-2A</td>
<td>not used</td>
<td>6 1/4</td>
</tr>
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<td>1-8 UNC-2A</td>
<td>not used</td>
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<td>8</td>
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<td>2 1/4</td>
<td>1-8 UNC-2A</td>
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<td>7 1/4</td>
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<td>2 7/16</td>
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*1 in. = 25.4 mm.

### TABLE 8 Bolting Lengths for 150-lb Bronze Flanged Joints to ANSI B16.24 (see Fig. 1 and Fig. 2)

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<td>1⁄2-13 UNC-2A</td>
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<td>1⁄2-13 UNC-2A</td>
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<td>3½</td>
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<td>3⁄4</td>
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<td>4½</td>
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<td>4½</td>
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<td>7⁄8-9 UNC-2A</td>
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</table>

*1 in. = 25.4 mm.

### TABLE 9 Bolting Lengths for 300-lb Bronze Flanged Joints to ANSI B16.24 (see Fig. 1 and Fig. 2)

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<td>7⁄16</td>
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<td>2½</td>
</tr>
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<td>5⁄8</td>
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<td>1⁄2-13 UNC-2A</td>
<td>1½</td>
<td>2½</td>
</tr>
<tr>
<td>1</td>
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<td>2½</td>
</tr>
<tr>
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<td>15⁄32</td>
<td>1⁄2-13 UNC-2A</td>
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</table>

*1 in. = 25.4 mm.

### TABLE 10 Bolting Lengths for 150-lb Steel Flat Face to Bronze Flanged Joints to ANSI B16.5 and B16.24 (see Fig. 1 and Fig. 2)

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<td>4</td>
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<td>1⁄2-13 UNC-2A</td>
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<td>4</td>
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<td>1⁄2-13 UNC-2A</td>
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</tr>
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<td>1⁄2</td>
<td>4</td>
<td>31⁄32</td>
<td>1⁄2-10 UNC-2A</td>
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<td>4½</td>
</tr>
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<td>1⁄2</td>
<td>4</td>
<td>31⁄32</td>
<td>1⁄2-10 UNC-2A</td>
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<td>4½</td>
</tr>
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<td>1⁄2</td>
<td>4</td>
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<tbody>
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<td></td>
<td></td>
<td>Steel</td>
<td>Bronze</td>
<td></td>
</tr>
<tr>
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<td>5/8</td>
<td>4</td>
<td>15/16</td>
<td>5/8</td>
<td>5/16-11 UNC-2A</td>
</tr>
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<td>5/8</td>
<td>8</td>
<td>15/16</td>
<td>11/16</td>
<td>5/16-11 UNC-2A</td>
</tr>
<tr>
<td>4</td>
<td>5/8</td>
<td>8</td>
<td>15/16</td>
<td>11/16</td>
<td>5/16-11 UNC-2A</td>
</tr>
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<td>8</td>
<td>15/16</td>
<td>3/4</td>
<td>5/16-10 UNC-2A</td>
</tr>
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<td>3/4</td>
<td>8</td>
<td>1</td>
<td>13/16</td>
<td>5/16-10 UNC-2A</td>
</tr>
<tr>
<td>8</td>
<td>3/4</td>
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<td>12</td>
<td>1 1/4</td>
<td>1 1/8</td>
<td>7/8-9 UNC-2A</td>
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</table>

A 1 in. = 25.4 mm.

### TABLE 11  Bolting Lengths for 300-lb Steel Flat Face to Bronze Flanged Joints to ANSI B16.5 and B16.24 (see Fig. 1 and Fig. 2)

<table>
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</thead>
<tbody>
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<td></td>
<td></td>
<td>Steel</td>
<td>Bronze</td>
<td></td>
</tr>
<tr>
<td>1/2</td>
<td>1/2</td>
<td>4</td>
<td>9/16</td>
<td>1/2</td>
<td>1/2-13 UNC-2A</td>
</tr>
<tr>
<td>3/4</td>
<td>1/2</td>
<td>4</td>
<td>1/2</td>
<td>17/32</td>
<td>1/2-13 UNC-2A</td>
</tr>
<tr>
<td>1</td>
<td>1/2</td>
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<td>19/32</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>1 1/4</td>
<td>3/4</td>
<td>4</td>
<td>3/4</td>
<td>5/8</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>1 1/2</td>
<td>3/4</td>
<td>4</td>
<td>3/4</td>
<td>3/4</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
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<td>3/4</td>
<td>8</td>
<td>7/8</td>
<td>13/16</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>2 1/2</td>
<td>3/4</td>
<td>8</td>
<td>1</td>
<td>13/16</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>3</td>
<td>3/4</td>
<td>8</td>
<td>1 1/2</td>
<td>25/32</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>3 1/2</td>
<td>3/4</td>
<td>8</td>
<td>13/16</td>
<td>31/32</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>4</td>
<td>3/4</td>
<td>8</td>
<td>1 1/4</td>
<td>13/16</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>5</td>
<td>3/4</td>
<td>8</td>
<td>1 1/4</td>
<td>13/16</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>6</td>
<td>3/4</td>
<td>12</td>
<td>1 1/4</td>
<td>13/16</td>
<td>1/2-10 UNC-2A</td>
</tr>
<tr>
<td>8</td>
<td>7/8</td>
<td>12</td>
<td>1 1/4</td>
<td>1 1/8</td>
<td>1/2-9 UNC-2A</td>
</tr>
</tbody>
</table>

A 1 in. = 25.4 mm.

### TABLE 12  Bolting Lengths for 125-lb Cast Iron to 150-lb Steel Flat Face Flanged Joints to MSS SP-44, ANSI B16.1, and ANSI B16.5 (see Fig. 1 and Fig. 2)

<table>
<thead>
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</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td>Cast Iron</td>
<td>Steel</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1/2</td>
<td>4</td>
<td>7/16</td>
<td>5/8</td>
<td>1/2-13 UNC-2A</td>
</tr>
<tr>
<td>1 1/4</td>
<td>1/2</td>
<td>4</td>
<td>1/2</td>
<td>5/8</td>
<td>1/2-13 UNC-2A</td>
</tr>
<tr>
<td>1 1/2</td>
<td>1/2</td>
<td>4</td>
<td>5/16</td>
<td>11/16</td>
<td>1/2-13 UNC-2A</td>
</tr>
<tr>
<td>2</td>
<td>5/8</td>
<td>4</td>
<td>5/8</td>
<td>3/4</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>2 1/2</td>
<td>5/8</td>
<td>4</td>
<td>11/16</td>
<td>3/4</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>3</td>
<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>15/16</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>3 1/2</td>
<td>5/8</td>
<td>8</td>
<td>13/16</td>
<td>15/16</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>4</td>
<td>5/8</td>
<td>8</td>
<td>13/16</td>
<td>15/16</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>4 through 24</td>
<td>5/8</td>
<td>8</td>
<td>13/16</td>
<td>15/16</td>
<td>1/2-11 UNC-2A</td>
</tr>
<tr>
<td>30</td>
<td>1 1/2</td>
<td>28</td>
<td>2 1/6</td>
<td>2 15/16</td>
<td>1 1/4-7 UNC-2A</td>
</tr>
<tr>
<td>36</td>
<td>1 1/2</td>
<td>32</td>
<td>2 1/6</td>
<td>3 1/16</td>
<td>1 1/4-6 UNC-2A</td>
</tr>
</tbody>
</table>

A 1 in. = 25.4 mm.

For dimensions of these pipe sizes, refer to Table 1.
### TABLE 13 Bolting Lengths for 250-lb Cast Iron to 300-lb Steel Flat Face Flanged Joints to ANSI B16.1 and B16.5

(see Fig. 1 and Fig. 2)

<table>
<thead>
<tr>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 through 24</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

*a* 1 in. = 25.4 mm.

*b* For dimensions on these pipe sizes, refer to Table 2.

### TABLE 14 Bolting Lengths for 800-lb Cast Iron to 600-lb Steel Flanged Joints to ANSI B16.1 and B16.5

(see Fig. 3 and Fig. 4)

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5/8</td>
<td>8</td>
<td>1 1/2</td>
<td>1/8</td>
<td>5/8-10 UNC-2A</td>
<td>not used</td>
</tr>
<tr>
<td>2 1/2</td>
<td>5/8</td>
<td>8</td>
<td>1 1/2</td>
<td>1/8</td>
<td>5/8-10 UNC-2A</td>
<td>not used</td>
</tr>
<tr>
<td>3</td>
<td>5/8</td>
<td>8</td>
<td>1 1/2</td>
<td>1/2</td>
<td>5/8-10 UNC-2A</td>
<td>not used</td>
</tr>
</tbody>
</table>

*a* 1 in. = 25.4 mm.

### TABLE 15 Bolting Lengths for Wafer-Type Butterfly Valve and 150-lb Steel Flanges to ANSI B16.5

(see Fig. 5 and Fig. 6)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>1 1/4</td>
<td>5/8-11 UNC-2A</td>
<td>4 1/4</td>
<td>4 1/4</td>
</tr>
<tr>
<td>2 1/4</td>
<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>1 1/4</td>
<td>5/8-11 UNC-2A</td>
<td>4 1/4</td>
<td>4 1/4</td>
</tr>
<tr>
<td>3</td>
<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>1 1/4</td>
<td>5/8-11 UNC-2A</td>
<td>4 1/4</td>
<td>4 1/4</td>
</tr>
<tr>
<td>3 1/2</td>
<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>1 1/4</td>
<td>5/8-11 UNC-2A</td>
<td>4 1/4</td>
<td>4 1/4</td>
</tr>
<tr>
<td>4</td>
<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>1 1/4</td>
<td>5/8-11 UNC-2A</td>
<td>4 1/4</td>
<td>4 1/4</td>
</tr>
<tr>
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<td>5/8</td>
<td>4</td>
<td>3/4</td>
<td>1 1/4</td>
<td>5/8-11 UNC-2A</td>
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*a* 1 in. = 25.4 mm.

### TABLE 16 Bolting Lengths for Wafer-Type Butterfly Valve and 150-lb Bronze Flanges to ANSI B16.24

(see Fig. 5 and Fig. 6)

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<td>5/8</td>
<td>4</td>
<td>1/2</td>
<td>1/4</td>
<td>5/8-11 UNC-2A</td>
<td>3/4</td>
<td>4 1/4</td>
</tr>
<tr>
<td>2 1/4</td>
<td>5/8</td>
<td>4</td>
<td>1/2</td>
<td>1/4</td>
<td>5/8-11 UNC-2A</td>
<td>3/4</td>
<td>4 1/4</td>
</tr>
<tr>
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<td>5/8</td>
<td>4</td>
<td>1/2</td>
<td>1/4</td>
<td>5/8-11 UNC-2A</td>
<td>3/4</td>
<td>4 1/4</td>
</tr>
<tr>
<td>3 1/2</td>
<td>5/8</td>
<td>4</td>
<td>1/2</td>
<td>1/4</td>
<td>5/8-11 UNC-2A</td>
<td>3/4</td>
<td>4 1/4</td>
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<tr>
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<td>5/8</td>
<td>4</td>
<td>1/2</td>
<td>1/4</td>
<td>5/8-11 UNC-2A</td>
<td>3/4</td>
<td>4 1/4</td>
</tr>
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<td>1/2</td>
<td>1/4</td>
<td>5/8-11 UNC-2A</td>
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*a* 1 in. = 25.4 mm.
TABLE 16  Continued

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<td>13⁄16</td>
<td>21⁄8</td>
<td>3⁄4-10 UNC-2A</td>
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<td>8</td>
<td>15⁄16</td>
<td>21⁄8</td>
<td>3⁄4-10 UNC-2A</td>
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<td>7⁄8-9 UNC-2A</td>
<td>61⁄2</td>
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</table>

*1 in. = 25.4 mm.

TABLE 17  Bolting Lengths for Tapped Lug-Type Butterfly Valve and 150-lb Steel Flanges to ANSI B16.5 (see Fig. 7)

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<td>8</td>
<td>3⁄4</td>
<td>11⁄16</td>
<td>5⁄8-11 UNC-2A</td>
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<tr>
<td>21⁄4</td>
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<td>8</td>
<td>5⁄8</td>
<td>3</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
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<td>8</td>
<td>15⁄16</td>
<td>11⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
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<tr>
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<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>31⁄4</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
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<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
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<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
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<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
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<tr>
<td>8</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
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<tr>
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<td>7⁄8</td>
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<td>7⁄8-9 UNC-2A</td>
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<tr>
<td>12</td>
<td>7⁄8</td>
<td>24</td>
<td>11⁄16</td>
<td>3</td>
<td>7⁄8-9 UNC-2A</td>
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</tr>
<tr>
<td>14</td>
<td>7⁄8</td>
<td>24</td>
<td>11⁄16</td>
<td>3</td>
<td>7⁄8-9 UNC-2A</td>
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</tr>
<tr>
<td>16</td>
<td>7⁄8</td>
<td>24</td>
<td>11⁄16</td>
<td>3</td>
<td>7⁄8-9 UNC-2A</td>
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</tr>
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<td>18</td>
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<td>3</td>
<td>11⁄8-7 UNC-2A</td>
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</tr>
<tr>
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<td>11⁄8</td>
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<td>15⁄16</td>
<td>4</td>
<td>11⁄8-7 UNC-2A</td>
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<td>11⁄4</td>
<td>40</td>
<td>15⁄16</td>
<td>51⁄2</td>
<td>11⁄4-7 UNC-2A</td>
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</tr>
<tr>
<td>30</td>
<td>11⁄4</td>
<td>56</td>
<td>215⁄16</td>
<td>61⁄2</td>
<td>11⁄4-7 UNC-2A</td>
<td>5</td>
</tr>
</tbody>
</table>

*1 in. = 25.4 mm.

TABLE 18  Bolting Length for Tapped Lug-Type Butterfly Valve and 150-lb Bronze Flanges to ANSI B16.24 (see Fig. 7)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5⁄8</td>
<td>8</td>
<td>3⁄4</td>
<td>11⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>21⁄4</td>
<td>5⁄8</td>
<td>8</td>
<td>5⁄8</td>
<td>3</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>3</td>
<td>5⁄8</td>
<td>8</td>
<td>15⁄16</td>
<td>11⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>31⁄2</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>31⁄4</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>4</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>5</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>6</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>8</td>
<td>5⁄8</td>
<td>16</td>
<td>15⁄16</td>
<td>111⁄16</td>
<td>5⁄8-11 UNC-2A</td>
<td>11⁄2</td>
</tr>
<tr>
<td>10</td>
<td>7⁄8</td>
<td>24</td>
<td>1</td>
<td>21⁄2</td>
<td>7⁄8-9 UNC-2A</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>7⁄8</td>
<td>24</td>
<td>11⁄16</td>
<td>3</td>
<td>7⁄8-9 UNC-2A</td>
<td>2</td>
</tr>
</tbody>
</table>

*1 in. = 25.4 mm.
Note—Raised face shown, flat face similar.

FIG. 1 Flange Bolt Assembly for 125- to 300-psi Flanges

FIG. 2 Flange Stud Bolt Assembly for 125- to 300-psi Flanges
FIG. 3 Flange Bolt Assembly for 400-psi and Above Flanges

FIG. 4 Flange Stud Bolt Assembly for 400-psi and Above Flanges
FIG. 5 Butterfly Valve Stud Bolt Assembly with 150-psi Steel or Bronze Flanges

FIG. 6 Butterfly Valve Bolt Assembly with 150-psi Steel or Bronze Flanges
A1. METHOD FOR CALCULATING BOLTING LENGTHS

A1.1 The following equations were used in determining bolt and stud bolt lengths in Tables 1-16 and are included in this annex for computing bolting lengths not shown in these tables.

A1.1.1 Bolting lengths for flange to flange joints are computed using the following equation:

\[
L_{SB} = 2T + 2N + G + 2t + 2F + n \quad (A1.1)
\]

\[
L_{MB} = 2T + N + G + 2t + 2F + n \quad (A1.2)
\]

where:
- \( L_{SB} \) = length of stud bolt (effective thread length excluding point height),
- \( L_{MB} \) = length of machine bolt as measured from underside of head to first thread,
- \( T \) = minimum flange thickness,
- \( t \) = plus tolerance for flange thickness in accordance with ANSI B16.5,
- \( N \) = maximum height of nut (heavy hex) in accordance with ANSI B18.2.2,
- \( G \) = \( \frac{1}{8} \)-in. gasket thickness (maximum),
- \( F \) = height of raised face where not included in flange thickness, and
- \( n \) = negative bolting length tolerance in accordance with ANSI B18.2.1.

A1.1.2 Bolting lengths for wafer-type butterfly valves (commercial grade) installed between pipe flanges are computed using the following equation:

\[
L_{MB} = 2T + N + V + 2t + n \quad (A1.3)
\]

where:
- \( L_{MB} \) = length of machine bolt as measured from underside of head to first thread,
- \( L_{SB} \) = length of stud bolt excluding point height,
- \( T \) = minimum flange thickness,
- \( t \) = plus tolerance for flange thickness in accordance with ANSI B16.5,
- \( N \) = maximum height of nut (heavy hex) in accordance with ANSI B18.2.2,
- \( V \) = thickness of butterfly valve,
- \( n \) = negative stud bolt length tolerance in accordance with ANSI B18.2.1.

A1.1.3 Bolt lengths for tapped lug-type butterfly valves (commercial grade) installed between pipe flanges are computed using the following equation:

\[
L_{MB} = T + \frac{V}{2} \quad (A1.5)
\]

where:
- \( L_{MB} \) = length of machine bolt as measured from underside of head to first thread,
- \( T \) = minimum flange thickness, and
- \( V \) = thickness of butterfly valve.

\[\text{NOTE A1.1—Rounding-off bolt or stud bolt length to} \ 0.25\text{-in. (6.3-mm) increments: where } L_{SB} \text{ or } L_{MB} \text{ is 0.10 in. or more greater than any } 0.25\text{-in. increment, round off upward; if less than 0.10 in., round off downward to next } 0.25\text{-in. increment. } L_{MB} \text{ for tapped lug-type butterfly valve, round off downward to next } 0.25\text{-in. increment.} \]

\[\text{NOTE A1.2—Users are reminded that removing the raised face will} \]
make the flange thickness dimension nonstandard.

**NOTE A1.3**—Stud bolt lengths listed in Table 15 and Table 16 are sized to accommodate maximum width of all commercial grade wafer-type butterfly valves of up to 150-psi pressure rating.

**NOTE A1.4**—Bolt lengths listed in Table 17 and Table 18 are sized to accommodate minimum width of all commercial grade tapped lug-type butterfly valves of up to 150-psi pressure ratings.

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Standard Specification for Modular Gage Boards

This standard is issued under the fixed designation F 707/F707M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers modular gage boards for mounting 89-mm (3 1/2-in.), 114-mm (4 1/2-in.), 152-mm (6-in.), and 216-mm (8 1/2-in.) dial size pressure gages and dial thermometers for miscellaneous shipboard applications.

1.2 Gage boards ordered under this specification are suitable for pressure gages and dial thermometers with either turret or back flanged type cases and with either back or bottom connections (see Appendix X1).

1.3 Gage mounting dimensions shall be in accordance with ANSI B 40.1.

1.4 The values stated in metric units (SI) are to be regarded as the standard. The values given in parentheses (inch/pound) are provided for information purposes.

NOTE 1—Gage boards covered by this specification are those normally supplied by the shipyard as opposed to the shipyard’s equipment subcontractor.

2. Referenced Documents

2.1 ASTM Standards:
   B 40.1 Gages, Pressure and Vacuum, Indicating Dial Type—Elastic Element

2.2 Other Standards:
   Fed Spec. TT-P-645 Primer, Paint, Zinc-Chromate, Alkyd Type
   DoD-P-15328 Primer (Wash), Pretreatment (Formula No. 117 for Metals) (Metric)

3. Classification

3.1 Gage boards are furnished in two types as follows:
   3.1.1 Type I—Gage boards for mounting 89-mm (3 1/2-in.) and 114-mm (4 1/2-in.) dial size gages as specified in Section 5.
   3.1.2 Type II—Gage boards for mounting 152-mm (6-in.) and 216-mm (8 1/2-in.) dial size gages as specified in Section 5.

3.2 Gage boards are furnished in two grades as follows:
   3.2.1 Grade a—Gage boards are to be manufactured from carbon steel as specified in Section 5.
   3.2.2 Grade b—Gage boards are to be manufactured from aluminum alloy as specified in Section 5.

4. Ordering Information

4.1 Orders for gage boards under this specification shall include the following information:
   4.1.1 Quantity (number of gage boards),
   4.1.2 Name of item (gage board),
   4.1.3 Type (Type I or Type II as specified by purchaser), see 3.1.1 and 3.1.2,
   4.1.4 Grade (Grade a or Grade b as specified by purchaser), see 3.2.1 and 3.2.2,
   4.1.5 Paint (as specified by purchaser), see 7.2,
   4.1.6 Drilling for gage mounting (as specified by purchaser), see 5.1.1, and
   4.1.7 ASTM designation and date of issue.

5. Materials and Manufacture

5.1 Unless otherwise specified the gage boards shall be manufactured from 11-gage (manufacturers standard gage) carbon steel for Grade a and 3 mm (1/8 in.) thick aluminum alloy for Grade b. Materials shall be capable of being bent at room temperature through 90° in any direction to an inside radius equal to its thickness without cracking on the outside of the bent portion.

5.1.1 Unless otherwise specified, Type I gage boards shall be drilled for mounting both 89-mm (3 1/2-in.) and 114-mm (4 1/2-in.) dial size gages and Type II gage boards shall be drilled for mounting both 152-mm (6-in.) and 216-mm (8 1/2-in.) dial size gages. When specified by the purchaser, drilling shall be limited to one size gage for either Type I or Type II gage boards (see 4.1.6).

6. Dimensions and Permissible Variations

6.1 The dimensions of the gage board shall not vary by more than 0.4 mm (±1/64 in.) except as noted in Fig. 1 and Fig. 2.

7. Workmanship, Finish and Appearance

7.1 The gage boards shall have a workmanlike finish free of scale, burrs, cracks, and other defects affecting serviceability or appearance.
7.2 If paint is not specified by the purchaser, Grade a gage boards shall be supplied with a coat of zinc chromate primer in accordance with Federal Specification TT-P-645, Formula 84 or equal (yellow) 0.038-mm (1.5-mils) dry film thickness. Grade b gage boards shall be supplied with one pretreatment wash coat in accordance with Specification DOD-P-15328 Formula 117 or equal (dark green) 0.013-mm (0.5-mils) dry film thickness and one coat of zinc chromate primer in accordance with Federal Specification TT-P-645 Formula 84D or equal (dark green) 0.013 mm (1.5-mils) dry film thickness.

8. Product Marking

8.1 Each shipping unit shall bear a tag or be plainly marked with the following: ASTM designation number, name or trademark of manufacturer, number of pieces, and purchase order number.

9. Keywords

9.1 dial pressure gages; dial thermometers; modular gage boards; pressure gages
APPENDIX

X1. RATIONALE USED FOR DEVELOPMENT OF SPECIFICATION FOR MODULAR GAGE BOARDS

X1.1 This specification has been developed primarily to provide maximum versatility for the installation of 89-mm (3 1/2 -in.), 114-mm (4 1/2 -in.), 152-mm (6-in.), and 216-mm (8 1/2 -in.) dial size simplex, duplex, and differential pressure gages and dial thermometers with either turret- or back-flanged cases. Fig. X1.1 Fig. X1.2 Fig. X1.3

X1.2 The gage board is suitable for single-gage installation, but has the versatility of being bolted together horizontally, vertically, in pyramid fashion or a combination thereof to provide for multigage installations utilizing both Type I and Type II gage boards.

X1.3 When used in horizontally arranged installations, either bottom or back connected pressure gages and dial

**FIG. X1.1 Bottom- and Back-Connected Pressure Gages for Horizontal Installations of Type I or Type II Gage Boards**
thermometers may be used. When used vertically or in combination with vertical, horizontal, or pyramid arrangements, back connected pressure gages and dial thermometers must be used.

X1.4 This specification does not cover flush-mounted gages.
1. Scope

1.1 This specification covers modular gage boards for mounting 89-mm (3½-in.), 114-mm (4½-in.), 152-mm (6-in.), and 216-mm (8½-in.) dial size pressure gages and dial thermometers for miscellaneous shipboard applications.

1.2 Gage boards ordered under this specification are suitable for pressure gages and dial thermometers with either turret or back flanged type cases and with either back or bottom connections (see Appendix X1).

1.3 Gage mounting dimensions shall be in accordance with ANSI B 40.1.

1.4 The values stated in metric units (SI) are to be regarded as the standard. The values given in parentheses (inch/pound) are provided for information purposes.

2. Referenced Documents

2.1 ASTM Standards:
B 40.1 Gages, Pressure and Vacuum, Indicating Dial Type—Elastic Element

2.2 Other Standards:
Fed Spec. TT-P-645 Primer, Paint, Zinc-Chromate, Alkyd Type
DoD-P-15328 Primer (Wash), Pretreatment (Formula No. 117 for Metals) (Metric)

3. Classification

3.1 Gage boards are furnished in two types as follows:

3.1.1 Type I—Gage boards for mounting 89-mm (3½-in.) and 114-mm (4½-in.) dial size gages as specified in Section 5.

3.1.2 Type II—Gage boards for mounting 152-mm (6-in.) and 216-mm (8½-in.) dial size gages as specified in Section 5.

3.1.2.1 Grade a—Gage boards are to be manufactured from carbon steel as specified in Section 5.

3.1.2.2 Grade b—Gage boards are to be manufactured from aluminum alloy as specified in Section 5.

4. Ordering Information

4.1 Orders for gage boards under this specification shall include the following information:

4.1.1 Quantity (number of gage boards),
4.1.2 Name of item (gage board),
4.1.3 Type (Type I or Type II as specified by purchaser), see 3.1.1 and 3.1.2,
4.1.4 Grade (Grade a or Grade b as specified by purchaser), see 3.2.1 and 3.2.2,
4.1.5 Paint (as specified by purchaser), see 7.2,
4.1.6 Drilling for gage mounting (as specified by purchaser), see 5.1.1, and
4.1.7 ASTM designation and date of issue.

5. Materials and Manufacture

5.1 Unless otherwise specified the gage boards shall be manufactured from 11-gage (manufacturers standard gage) carbon steel for Grade a and 3 mm (1/8 in.) thick aluminum alloy for Grade b. Materials shall be capable of being bent at room temperature through 90° in any direction to an inside radius equal to its thickness without cracking on the outside of the bent portion.

5.1.1 Unless otherwise specified, Type I gage boards shall be drilled for mounting both 89-mm (3½-in.) and 114-mm (4½-in.) dial size gages and Type II gage boards shall be drilled for mounting both 152-mm (6-in.) and 216-mm (8½-in.) dial size gages. When specified by the purchaser, drilling shall be limited to one size gage for either Type I or Type II gage boards (see 4.1.6).
6. Dimensions and Permissible Variations

6.1 The dimensions of the gage board shall not vary by more than 0.4 mm (± ⅖ in.) except as noted in Fig. 1 and Fig. 2.

7. Workmanship, Finish and Appearance

7.1 The gage boards shall have a workmanlike finish free of scale, burrs, cracks, and other defects affecting serviceability or appearance.

7.2 If paint is not specified by the purchaser, Grade a gage boards shall be supplied with a coat of zinc chromate primer in accordance with Federal Specification TT-P-645, Formula 84 or equal (yellow) 0.038-mm (1.5-mils) dry film thickness. Grade b gage boards shall be supplied with one pretreatment wash coat in accordance with Specification DOD-P-15328 Formula 117 or equal (dark green) 0.013-mm (0.5-mils) dry film thickness and one coat of zinc chromate primer in accordance with Federal Specification TT-P-645 Formula 84D or equal (dark green) 0.013 mm (1.5-mils) dry film thickness.

8. Product Marking

8.1 Each shipping unit shall bear a tag or be plainly marked with the following: ASTM designation number, name or trademark of manufacturer, number of pieces, and purchase order number.

9. Keywords

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X1.1 This specification has been developed primarily to provide maximum versatility for the installation of 89-mm (3½-in.), 114-mm (4½-in.), 152-mm (6-in.), and 216-mm (8½-in.) dial size simplex, duplex, and differential pressure gages and dial thermometers with either turret- or back-flanged cases (see Fig. X1.1 Fig. X1.2 Fig. X1.3).

X1.2 The gage board is suitable for single-gage installation, but has the versatility of being bolted together horizontally, vertically, in pyramid fashion or a combination thereof to
provide for multigage installations utilizing both Type I and Type II gage boards.

X1.3 When used in horizontally arranged installations, either bottom or back connected pressure gages and dial
thermometers may be used. When used vertically or in com-
bination with vertical, horizontal, or pyramid arrangements, 
back connected pressure gages and dial thermometers must be 
used.

X1.4 This specification does not cover flush-mounted
Standard Practice for Design and Installation of Rigid Pipe Hangers

1. Scope

1.1 This practice covers acceptable methods of fabricating and installing rigid pipe hangers used to support shipboard piping systems with temperatures of 650°F (343°C) or less.

1.2 This practice provides guidance for the design of hanger caps, straps and standoffs, selection of hanger and hanger liner materials, hanger bolting, and hanger spacing.

1.3 Other hanger designs may be used provided they result in an adequately supported vibration-free piping system and are compatible with the intended system service and temperature limitations.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards: 2

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

3. Terminology

3.1 Definitions:

3.1.1 liner—the material used to isolate a pipe from its hanger.

3.1.2 rider bar—a protective strip of material installed between the pipe and the hanger where frequent linear movement of the pipe is expected.

3.1.3 rigid pipe hanger—a device that transfers the load imposed by the piping, insulation, and system medium to the supporting structure.

3.1.4 standoff—the rigid member that connects the hanger strap, saddle, or band to the supporting structure. A standoff is usually made up of one or more pieces of flat bar, pipe, angle bar, or flanged plate to suit a specific location.

4. List of Pipe Hanger Styles

4.1 This practice incorporates 26 pipe hanger assemblies as shown on Figs. 1-12(c) as follows:

<table>
<thead>
<tr>
<th>Hanger</th>
<th>Fig. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Split cap hanger (single leg standoff)</td>
<td>1(a)</td>
</tr>
<tr>
<td>Split cap hanger (dual leg standoff)</td>
<td>1(b)</td>
</tr>
<tr>
<td>Split cap hanger (chair type)</td>
<td>1(c)</td>
</tr>
<tr>
<td>Strap hanger</td>
<td>2(a)</td>
</tr>
<tr>
<td>Strap hanger (assembled for clearance with rider bar)</td>
<td>2(b)</td>
</tr>
<tr>
<td>Strap hanger (assembled for clearance with TFE-fluorocarbon strip)</td>
<td>2(c)</td>
</tr>
<tr>
<td>Welded hanger (flat bar U-type)</td>
<td>3(a)</td>
</tr>
<tr>
<td>Welded hanger (round bar U-type)</td>
<td>3(b)</td>
</tr>
<tr>
<td>Welded hanger (square bar U-type)</td>
<td>3(b)</td>
</tr>
<tr>
<td>U-bolt hanger</td>
<td>4(a)</td>
</tr>
<tr>
<td>U-bolt hanger (assembled for clearance with rider bar)</td>
<td>4(b)</td>
</tr>
<tr>
<td>U-bolt hanger (assembled for clearance with TFE-fluorocarbon strip)</td>
<td>4(c)</td>
</tr>
<tr>
<td>Welded hanger (single leg standoff welded direct to pipe)</td>
<td>5(a)</td>
</tr>
<tr>
<td>Welded hanger (dual leg standoff welded direct to pipe)</td>
<td>5(b)</td>
</tr>
<tr>
<td>“J” band type hanger (insulated pipe)</td>
<td>6(a)</td>
</tr>
<tr>
<td>“J” band type hanger (bare pipe)</td>
<td>6(b)</td>
</tr>
<tr>
<td>Nelson® hanger</td>
<td>7</td>
</tr>
<tr>
<td>Clamp hanger assembled with mounting channel</td>
<td>8</td>
</tr>
<tr>
<td>Poly-block twin clamp hanger (assembled with welding plate)</td>
<td>9(a)</td>
</tr>
<tr>
<td>Poly-block twin clamp hanger (assembled with welding stud)</td>
<td>9(b)</td>
</tr>
<tr>
<td>Poly-block twin clamp hanger (assembled with welding stud)</td>
<td>9(c)</td>
</tr>
<tr>
<td>Crimp-on weld stud-type hangers</td>
<td>10</td>
</tr>
<tr>
<td>Banded weld stud-type hanger</td>
<td>11</td>
</tr>
<tr>
<td>Poly-block single-clamp hanger (assembled with welding plate)</td>
<td>12(a)</td>
</tr>
</tbody>
</table>

---


2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.
5. Hanger Designs

5.1 Figs. 1-5 and Fig. 6(a) hangers are designs generally manufactured by shipyards or their subcontractors. See also Tables 1-6.

5.2 Fig. 6, Fig. 8, Fig. 10, and Fig. 11 hangers are commercially available from various vendors. Fig. 8, Fig. 10, and Fig. 11 hangers are primarily designed for use in supporting electrical cables, but are suitable for hanging small size pipe and tubing.

5.2.1 The Fig. 7 hanger is a specific design that has been patented by Nelson Division of TRW.

5.2.2 The Fig. 9 and Fig. 12 hangers are primarily designed for use when supporting multiple runs of pipe or tubing.

6. Materials and Manufacture

6.1 Hanger materials for straps, saddles, and U-bolts for Figs. 1-5 hangers and standoffs should be fabricated from commercial quality carbon steel. The steel should be a weldable grade with a minimum tensile strength of 47 ksi (324 MPa) and capable of being bent at room temperature through 90° to an inside radius equal to the material thickness without cracking on the outside of the bend.

6.2 Hangers in Fig. 1, Fig. 6, Fig. 7, Fig. 10, and Fig. 11 are generally manufactured from carbon steel. Fig. 8 is furnished in carbon steel and stainless steel. Fig. 9 and Fig. 12 hanger clamp halves are injected molded plastic furnished with carbon steel or stainless steel hardware.

6.3 Bands and buckles for Fig. 6 and Fig. 11 hangers should be carbon steel electroplated zinc or stainless steel.

6.4 Hanger bolts and nuts should be regular series hex type electroplated zinc with unified national coarse threads Class 2 fit in accordance with Specification A 307, Grade B.

6.5 Table 7 is a listing of hanger liner materials generally used to isolate the pipe from the hanger (see 9.1.1).

---

6 The sole source of supply of the apparatus known to the committee at this time is TRW Nelson Div., Toledo Ave. and E. 28th St., Lorain, OH 44055. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

7 The sole source of supply of the apparatus known to the committee at this time is Stauff Corp., 41 Newman St., Hackensack, NJ 07601. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

8 The sole source of supply of the poly-block hangers known to the committee at this time is Behringer Corp., 108 Jabez St., Newark, NJ 07105. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.
<table>
<thead>
<tr>
<th>Nominal Pipe Size, in.</th>
<th>Copper Water Tube Size, in.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>J</th>
<th>K</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>3³⁄₄</td>
<td>3</td>
<td>1 ³⁄₁₆</td>
<td>1³⁄₈</td>
<td>⁵⁄₈</td>
<td>⁷⁄₈</td>
<td>⁹⁄₈</td>
<td>⁵⁄₈</td>
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1 in. = 25.4 mm.
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\(^A\) 1 in. = 25.4 mm.
### TABLE 4 Dimensions for U-Bolt Hangers (Fig. 4)

**Note:** U-bolt dimensions are presently under review. Some sizes specified in this table are considered to be excessive for the intended service and are not commercially available as standard products. A revision will be processed when the review is completed.

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^1 in. = 25.4 mm.

### TABLE 5 Dimensions for Welded Hanger (Fig. 5)

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^1 in. = 25.4 mm.
TABLE 6 Dimensions for “J” Band Hanger (Fig. 6)

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<td>1/8 x 1</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>1/2</td>
<td>...</td>
<td>1/8 x 1</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>3/4</td>
<td>...</td>
<td>1/8 x 1</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>...</td>
<td>1</td>
<td>1/8 x 1</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>1</td>
<td>...</td>
<td>1/8 x 1</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>...</td>
<td>1 1/4</td>
<td>1/8 x 1</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>1 1/2</td>
<td>...</td>
<td>1/8 x 2</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>2</td>
<td>...</td>
<td>1/8 x 2</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>...</td>
<td>2 1/2</td>
<td>1/8 x 2</td>
<td>15</td>
<td>0.030 x 1/2</td>
</tr>
<tr>
<td>3</td>
<td>...</td>
<td>3/16 x 2</td>
<td>15</td>
<td>0.030 x 3/16</td>
</tr>
<tr>
<td>...</td>
<td>3 1/2</td>
<td>3/16 x 2</td>
<td>15</td>
<td>0.030 x 3/16</td>
</tr>
<tr>
<td>4</td>
<td>...</td>
<td>3/16 x 2</td>
<td>15</td>
<td>0.030 x 3/16</td>
</tr>
</tbody>
</table>

A 1 in. = 25.4 mm.

TABLE 7 Pipe Hanger Liner Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness, in. (mm)</th>
<th>Temperature Range, °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woven fiber glass tape, non-reinforced with salvage edges</td>
<td>1/8 (3.2)</td>
<td>up to 650 (343.3)</td>
</tr>
<tr>
<td>Silicon rubber sheet (ZZ-R-765, Class 2, 60 Durometer or equal)</td>
<td>1/4 (3.2)</td>
<td>up to 450 (232.2)</td>
</tr>
<tr>
<td>Synthetic rubber sheet (MIL-R-6855, Class 2, 60 Durometer or equal)</td>
<td>1/4 (3.2)</td>
<td>up to 180 (82.2)</td>
</tr>
<tr>
<td>Sheet lead</td>
<td>1/16 to 1/8 (1.6 to 3.2)</td>
<td>up to 500 (260)</td>
</tr>
<tr>
<td>Fluorocarbon elastomer (Viton, Fluorel)</td>
<td>1/16 (3.2)</td>
<td>up to 650 (343.3)</td>
</tr>
</tbody>
</table>

Other materials may be used provided the materials selected are compatible with the intended service and temperature limitations.

Use of asbestos as a hanger liner material shall be prohibited due to the potential health hazard in working with this material.

Similar to Amatex Corp., Thermoglass style G65752 9731 finish, or Claretex Style 19-T-125 or equivalent.

Only oil-resistant synthetic rubber should be used in oil tanks.

TABLE 8 Pipe Hanger Spacing

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in.</th>
<th>Hanger Spacing, ft (m)</th>
<th>Nominal Pipe Size, in.</th>
<th>Hanger Spacing, ft (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>5 (1.52)</td>
<td>10</td>
<td>15 (4.57)</td>
</tr>
<tr>
<td>3/4</td>
<td>5 (1.52)</td>
<td>12</td>
<td>15 (4.57)</td>
</tr>
<tr>
<td>1</td>
<td>6 (1.82)</td>
<td>14</td>
<td>15 (4.47)</td>
</tr>
<tr>
<td>1 1/4</td>
<td>6 (1.82)</td>
<td>16</td>
<td>15 (4.47)</td>
</tr>
<tr>
<td>1 1/2</td>
<td>6 (1.82)</td>
<td>18</td>
<td>15 (4.47)</td>
</tr>
<tr>
<td>2</td>
<td>8 (2.44)</td>
<td>20</td>
<td>15 (4.47)</td>
</tr>
<tr>
<td>2 1/2</td>
<td>8 (2.44)</td>
<td>24</td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>3</td>
<td>8 (2.44)</td>
<td>26</td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>3 1/2</td>
<td>8 (2.44)</td>
<td>28</td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>4</td>
<td>8 (2.44)</td>
<td>30</td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>5</td>
<td>12 (3.65)</td>
<td>32</td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>6</td>
<td>12 (3.65)</td>
<td>34</td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>8</td>
<td>12 (3.65)</td>
<td>36</td>
<td>20 (6.10)</td>
</tr>
</tbody>
</table>
NOTE 1—For dimensions of hangers, see Table 1.
NOTE 2—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather, and can be used lined or unlined.
NOTE 3—For Fig. 1(b), length of standoff legs may be unequal and angle of attachment may vary as required to suit conditions.
NOTE 4—Maximum length of standoff “L” shall be as follows: flat bar = 18 in.; pipe = 30 in.; and angle bar = 42 in.

FIG. 1 Split Cap Hangers

Note 1—For dimensions of hangers, see Table 2.
Note 2—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather, and can be used lined or unlined.
Note 3—Install standard flat washers as necessary to unlined strap to provide 1/32 to 1/8-in. (0.8 to 3.2-mm) clearance for linear motion of piping when required.

FIG. 2 Strap Hangers
**NOTE 1**—For dimensions of hangers, see Table 3.

**NOTE 2**—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather, and are intended to be used unlined only.

**NOTE 3**—Weld as indicated for size 3-in. NPS and above. For 2½-in. NPS and below, weld hanger on outside only.

**FIG. 3 Welded Hangers**

**FIG. 4 U-Bolt Hangers**

**NOTE 1**—For dimensions of hangers, see Table 4.

**NOTE 2**—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather, and are intended to be used unlined.
NOTE 1—For dimensions of hangers, see Table 5.

NOTE 2—These hangers are limited to use on normally dry ferrous piping systems, such as sounding tubes. Air escapes and plumbing drains with a wall thickness of 0.200 in. (5.1 mm) or more.

NOTE 3—These hangers should not be used where takedown is required or in the steering gear room, inner bottoms, fore peak, aft peak or deep tanks, or other high vibration or inaccessible areas.

NOTE 4—For Fig. 5(b), length of standoff legs may be unequal and angle of attachment may vary as required to suit conditions.

FIG. 5 Welded Hangers

(a) Single Leg Standoff Welded Direct to Pipe

(b) Dual Leg Standoff Welded Direct to Pipe
NOTE 1—For dimensions of hangers, see Table 6.

NOTE 2—These hangers are suitable for use in all locations, except tanks and areas exposed to the weather, and can be used lined or unlined.

FIG. 6 J-Band Type Hangers
NOTE 1—This hanger is suitable for use in all locations except tanks.

NOTE 2—This hanger is limited to use on pipe 4-in. NPS and below with a system operating temperature of 200°F (93.3°C) or less.

FIG. 7 Nelson Hanger

Note 1—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather. When used in areas subject to high corrosion, such as salt water ballast tanks or weather decks, stainless steel hanger components shall be used.

Note 2—These hangers are suitable for supporting single or multiple runs of piping 2 in. (50.8 mm) or smaller.

FIG. 8 Clamp Hanger Assembled with Mounting Channel
**F 708 – 92 (2004)**

**NOTE 1**—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather. When used in areas subject to high corrosion, such as salt water ballast tanks or weather decks, stainless steel hanger components shall be used.

**NOTE 2**—These hangers are limited to use on pipe 1 1/4-in. NPS and below and tubing 1 1/2-in. outside diameter and below with a system operating temperature of 300°F (149°C) or less.

**NOTE 3**—These hangers may be used for multiple pipe installations installed vertically, horizontally, or stacked using a welding plate, welding stud, or attached to a mounting channel.

---

**FIG. 9 Stauff Twin Clamp Hanger**

**NOTE 1**—These hangers are suitable for use in all locations, except tanks, and should be coated with neoprene or other similar material when used to support nonferrous tubing.

**NOTE 2**—These hangers are limited to use on tubing with an outside diameter of 1 1/8 in. (28.6 mm) or smaller with a system operating temperature of 180°F (82.2°C) or less.

**NOTE 3**—Size and quantity of tubes may be varied provided they are arranged so as to be securely clamped.

**FIG. 10 Crimp-On Weld Stud Hangers**
NOTE 1—These hangers are suitable for use in all locations except tanks.

NOTE 2—These hangers are limited to use on tubing with an outside diameter of ½ in. (12.7 mm) or smaller with a system operating temperature of 180°F (82.2°C) or less.

NOTE 3—Size and quantity of tube may be varied, provided they are arranged so as to be securely clamped.

**FIG. 11 Banded Weld Stud Hanger**

NOTE 1—These single poly-block hangers are available in Standard Duty and Heavy Duty Series dependent upon application.

NOTE 2—These hangers are suitable for use in all locations, including tanks and areas exposed to the weather. When used in areas subject to high corrosion, such as salt water ballast tanks or weather decks, stainless steel hanger components shall be used.

NOTE 3—These hangers are limited to use on pipe 8-in. NPS and below and tubing 8-in. outside diameter and below with a system operating temperature of 300°F (149°C) or less.

NOTE 4—These hangers may be used for multiple pipe installations installed vertically, horizontally, or stacked using a weld plate, weld stud, or attached to a mounting channel.

**FIG. 12 Poly-block Clamp Hangers**
Standard for
Shipbuilders and Marine Paints and Coatings Product/
Procedure Data Sheet

This standard is issued under the fixed designation F 718; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 The Shipbuilders and Marine Paints and Coatings
Product/Procedure Data Sheet provides on one sheet needed
information concerning the characteristics of a specific paint or
coating to include generic description, physical properties,
surface preparation requirements, application requirements,
and safety. The front side of the sheet contains four major,
numbered paragraphs and a highlighted section for
Special Safety Precautions. These paragraphs are as follows:
I. Generic Type and Description
II. Manufacturers Data
III. Properties
IV. Surface Preparation Minimum Requirements

The back side of the page contains the following paragraphs:
V. Mixing Procedure
VI. Application.

1.2 The completed data sheets can be used by technical
personnel to help evaluate the technical acceptability of a
proposed material, by production personnel to evaluate pro-
duction compatibility of proposed materials and to provide
application instructions for selected paints and coatings mater-
ials, and by quality control personnel to verify attributes of
materials.

2. Referenced Documents

2.1 ASTM Standards:
D 56 Test Method for Flash Point by Tag Closed Tester
D 93 Test Methods for Flash Point by Pensky-Martens
Closed Cup Tester
D 523 Test Method for Specular Gloss
D 1650 Test Methods of Sampling and Testing Shellac
Varnish
D 2697 Test Method for Volume Nonvolatile Matter in
Clear or Pigmented Coatings
D 3278 Test Method for Flash Point of Liquids by Small
Scale Closed Cup Apparatus

2.2 Method
24 U. S. Environmental Protection Agency, 40 CFR Ch. 1,
Part 60, Appendix A, Determination of Volatile Matter
Content, Density, Volume Solids, and Weight Solids of
Surface Coatings

3. Instructions for Completing Data Sheet

3.1 When filling out the Product/Procedure Data Sheet (see
Figs. 1 and 2) remember that the information contained therein
will be utilized by both technical and production personnel.
Keep it simple and brief but complete. The following instruc-
tions are organized by paragraph numbers contained within the
data sheet. Also see the two examples attached (Appendix X1).

3.2 Paragraph I—Generic Type and Description—Use only
known and industry-accepted generic descriptions. See Fig. 1.

3.3 Paragraph II—Manufacturers Data—This section is
self-explanatory with the possible exception of subparagraph
(f). This can be as complete or as brief as the concerned parties
desire. For example, a separate attached list of compatible and
incompatible topcoats or acceptable cargo exposures could be
included. See Fig. 1.

3.4 Paragraph III—Properties—This section is self-
explanatory with the possible exception of subparagraph (a).
If agreed upon by the concerned parties, a different method for
determining volume solids (theoretical coverage) may be
substituted. The form should be amended to show method. See
Fig. 1.

3.5 Special Safety Precautions—This section should con-
tain specific instructions of what to do in the event of skin or
eye contact or accidental ingestion, or both. Reference should

---

1 This standard is under the jurisdiction of ASTM Committee F25 on Ships and
Marine Technology and is the direct responsibility of Subcommittee F25.01 on
Structures.


2 Copies of the data sheet are available at a nominal charge from ASTM
Headquarters, 100 Barr Harbor Dr., PO Box C700, West Conshohocken, PA
19428-2959. Request Adjunct No. ADJF0718.

3 Annual Book of ASTM Standards, Vol 05.01.

4 Annual Book of ASTM Standards, Vol 06.01.

5 Withdrawn. See 1997 Annual Book of ASTM Standards, Vol 06.03.

6 Superintendent of Documents, Government Printing Office, Washington, DC
20402.
also be made to the appropriate manufacturer’s Material Safety Data Sheet. See Fig. 1.

3.6 Paragraph IV—Surface Preparation Minimum Requirements:

3.6.1 Subparagraphs (a) and (b)—Use an agreed-upon standard that is, ASTM, SSPC, Swedish, NACE, SNAME, etc. See Fig. 1.

3.6.2 Subparagraph (c)—Profile data are optional. If used, the profile listed must be given as a range. The method of measurement must be agreed upon by all parties concerned, or this paragraph can be left blank and the type and size of abrasive(s) allowed entered in subparagraph (d), Special Instructions. See Fig. 1.

3.7 Paragraph V—Mixing Procedure—This section is self-explanatory with the possible exceptions of subparagraphs (c) and (f). Subparagraph (c) should preferably contain a generic solvent as opposed to a proprietary one. Subparagraph (f) should, as a minimum, contain the mesh size of the straining material and special procedures governing which component should be added to the other. Subparagraph (b), if appropriate, should include length of induction time given as a function of various temperatures. See Fig. 2.

3.8 Paragraph VI—Application—This section is one of the most important of the entire form. It must be filled out accurately and completely using all blocks in every paragraph. Subparagraph (c), “Dry Times,” is to be used for tank coatings,
V. MIXING PROCEDURE:

(a) MIXING RATIOS BY WEIGHT -
    BY VOLUME -

(b) INDUCTION TIME -

(c) RECOMMENDED SOLVENT - THINNING -
    CONFINED AREAS -
    NON-CONFINED AREAS -
    CLEAN UP -

(d) THINNING REQUIREMENTS (RATIO) -

(e) POT LIFE -
    Hr(s) @ _______ 'C
    Hr(s) @ _______ 'C
    Hr(s) @ _______ 'C

(f) SPECIAL INSTRUCTIONS -

VI. APPLICATION:

(a) ENVIRONMENTAL LIMITATIONS -
    * TEMP. MIN. _______ MAX. _______
    * % RELATIVE HUMIDITY MIN. _______ MAX. _______

(b) FILM THICKNESS (SSPC PA2-73T) - WET MIN. _______ WET MAX. _______
    DRY MIN. _______ DRY MAX. _______

(c) DRY TIMES (ASTM D 1650)-RECOAT MIN.
    Hr(s) @ _______ 'C @ % R.H.
    Hr(s) @ _______ 'C @ % R.H.
    Hr(s) @ _______ 'C @ % R.H.

    MAX. _______ Hr(s) @ _______ 'C
    TO HANDLE MIN.
    Hr(s) @ _______ 'C @ % R.H.
    Hr(s) @ _______ 'C @ % R.H.
    Hr(s) @ _______ 'C @ % R.H.

    FOR IMMERSION MIN.
    Hr(s) @ _______ 'C
    Hr(s) @ _______ 'C
    Hr(s) @ _______ 'C

    MAX. _______ Hr(s) @ _______ 'C

(d) EQUIPMENT REQUIREMENTS (INCLUDE PREFERRED, SUITABLE AND NOT SUITABLE
    REQUIREMENTS).

(e) SPECIAL INSTRUCTIONS -

* CAUTION SHOULD BE TAKEN THAT SURFACE TEMPERATURE IS AT LEAST 5'0 ABOVE D.EW POINT.

FIG. 2 Data Sheet (Back)
underbottoms, and other specialty areas. Maximum recoat times should be expressed in hours, days, weeks, or months. Equipment requirements should be brief. See Fig. 2.

4. Keywords

4.1 data sheet; marine coatings; marine paints; procedure data sheet; product data sheet

APPENDIX

(Nonmandatory Information)

XI. SAMPLE SHEETS
**SHIPSBUILDERS AND MARINE**

**PAINTS AND COATINGS**

**PRODUCT/PROCEDURE DATA SHEET NO.** 2-1-1

<table>
<thead>
<tr>
<th>Date:</th>
<th>Rev.</th>
</tr>
</thead>
</table>

### I. GENERIC TYPE AND DESCRIPTION:
- Epoxy Polyamide

<table>
<thead>
<tr>
<th>Specification Number (If Applicable):</th>
<th>MIL-F-23236</th>
</tr>
</thead>
</table>

### II. MANUFACTURER DATA:
- **MANUFACTURER:** R-Equal Paint Mfg. Co.
- **PRODUCT DESIGNATION:** 40-DX, Red 40-DX-16, White 40-DX-17, Blue 40-DX-18
- **COLOR(S):** Red, White, Blue
- **USES:** Ballast Tanks
- **TECHNICAL SERVICE REPRESENTATIVE**
  - (Include Telephone No.) (000) 000-0000
  - Mr. Good Brush (000). 000-0000 (FAX)
- **NOT RECOMMENDED FOR:** High temperature service above 80°C

### III. PROPERTIES:
- **% VOLUME SOLIDS (ASTM D 2697):** 50%
- **FLASH POINT (ASTM TEST METHOD D 93); OR (ASTM TEST METHOD D 56);**
  - **OR (ASTM TEST METHOD D 3278):** 35°C
- **WEIGHT PER GALLON (FTMS141a4184.1):** 1.4 kg/l
- **SHELF LIFE:** 24 months
- **VIS COSITY (FTMS141a4281):** 120 K.U.
- **PACKAGING:** 2 premeasured metal containers, one packaged inside the other
- **NUMBER OF COMPONENTS:** 2
- **STORAGE REQUIREMENTS:** TEMP.
  - MIN. -18°C
  - MAX. 60°C
- **GLOSS (ASTM D 523):** Eggshell
- **VOLATILE ORGANIC COMPOUND (EPA TEST METHOD 24):**
- **WEIGHT OF DRY FILM (WEIGHT PER AREA AT A GIVEN THICKNESS):**

### SPECIAL SAFETY PRECAUTIONS:
- Harmful if inhaled. Could cause skin irritation and may cause respiratory reaction. Keep away from excessive heat and open flame. Use only with adequate ventilation. See U.S. Department of Labor Material Safety Data Sheet for additional information

### IV. SURFACE PREPARATION MINIMUM REQUIREMENTS (USE SPECIFIC STANDARD NUMBERS):
- **INITIAL -** Near White Blast, SSFC-SP-10
  - For Recoat - First coat must be clean and dry. Mechanically etch if recoat time has expired
- **TOUCH-UP -** Same as above. Limited power tool cleaning using disk grinders
- **PROFILE (INCLUDE METHOD USED):** Gardner Model 123 Profile meter
  - MIN. 40 MIC. MAX. 100 MIC.
- **SPECIAL INSTRUCTIONS:** Do not use power wire brush
- **PRIMER REQUIREMENTS (IF APPLICABLE):** Material is self-priming. The first coat is considered the prime coat

*FIG. X1.1 Sample Sheet (Front)*
V. MIXING PROCEDURE:
(a) MIXING RATIO BY WEIGHT - 3.6\text{kg} powder to 2.6\text{kg} liquid
BY VOLUME - 1 liter powder to 3.1 liters liquid
(b) INDUCTION TIME - none
(c) RECOMMENDED SOLVENT - THINNING -
CONFINED AREAS - #1 Solvent
NON-CONFINED AREAS - #2 Solvent
CLEAN UP - Cellosolve Acetate
(d) THINNING REQUIREMENTS (RATIO) - 10 % maximum
(e) POT LIFE -

\begin{tabular}{ccc}

\text{Hr(s)} & 4 & 4 \\
\text{C}   &   & C
\end{tabular}

\begin{tabular}{ccc}

\text{Hr(s)} & 24 & 4 \\
\text{C}   &   & C
\end{tabular}

(f) SPECIAL INSTRUCTIONS -
Strain mixture through #30 mesh screen.
Keep mixture under constant agitation.
Do not thin in VOC compliant areas.

VI. APPLICATION:
(a) ENVIRONMENTAL LIMITATIONS -
\begin{tabular}{ccc}

\text{TEMP. MIN.} & \text{-80°C} & \text{MAX.} & \text{80°C} \\
\text{% RELATIVE HUMIDITY MIN.} & 40% & \text{MAX.} & 95%
\end{tabular}

(b) FILM THICKNESS (SSPC PA2-73T) - WET MIN. 3.0 WET MAX. See Special Instructions
DRY MIN. 0.7 DRY MAX. See Special Instructions
(c) DRY TIMES (ASTM D 1650)-RECOAT
\begin{tabular}{ccc}

\text{MIN.} & 24 & \text{Hr(s)} \text{MIN.} & 18 & \text{C} \text{MIN.} & 14 \text{Hr(s)} \text{MIN.} & 10 \text{C} \\
\text{MAX.} & & \text{Hr(s)} & & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)}
\end{tabular}

TO HANDLE
\begin{tabular}{ccc}

\text{MIN.} & 0.25 & \text{Hr(s)} & \text{MAX.} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} \\
\text{MIN.} & 1.50 & \text{Hr(s)} & \text{MAX.} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)}
\end{tabular}

FOR IMMERSION
\begin{tabular}{ccc}

\text{MIN.} & \text{N.A.} & \text{Hr(s)} & \text{MAX.} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} \\
\text{MIN.} & \text{N.A.} & \text{Hr(s)} & \text{MAX.} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)} & & \text{Hr(s)}
\end{tabular}

(d) EQUIPMENT REQUIREMENTS (INCLUDE PREFERRED, SUITABLE AND NOT SUITABLE REQUIREMENTS).
Conventional spray-agitated pot, external mix gun with heavy-duty spring & 1.8m/mtip combination.
Airless spray - 8m/m with 80-185bar fluid pressure.
Brush - Use only for minor touch-up
Roller - Do not use.

(e) SPECIAL INSTRUCTIONS - Film thickness must be uniformly correct to facilitate welding and burning operations. No impact on performance. Qualified for use with the following welding processes: SAW, Flux Core, Short Arc, HIG, and Stick. Contact Technical Representative in Para. II(e) for parameters.

* CAUTION SHOULD BE TAKEN THAT SURFACE TEMPERATURE IS AT LEAST 3°C ABOVE DEW POINT.

FIG. X1.2 Sample Sheet (Back)
I. GENERIC TYPE AND DESCRIPTION:
Specification Number (If Applicable): Alky (Solvent-Based) Inorganic Zinc Silicate Primer

II. MANUFACTURERS DATA:
(a) MANUFACTURER: R-Equal Paint Mfg. Co.
(b) PRODUCT DESIGNATION: 86-DC-1 Gray
(c) COLOR(S): Gray
(d) USES: Preconstruction Primer
(e) TECHNICAL SERVICE REPRESENTATIVE
   (include Telephone Nos.): (100) 242-6000
   Mr. Good Brush (000) 000-000 (FAX)
(f) NOT RECOMMENDED FOR: Immersion Service
   See Technical Representative for compatible topcoats

III. PROPERTIES:
(a) % VOLUME SOLIDS (ASTM D 2697): 30
(b) FLASH POINT (ASTM TEST METHOD D 93); OR (ASTM TEST METHOD D 56);
    OR (ASTM TEST METHOD D 927) 25°C
(c) WEIGHT PER GALLON (FTMS1414418.41): 1.4 kg/l
(d) SHELF LIFE: 9 months
(e) VISCOSITY (FTMS1414428.1): 78 K.U.
(f) PACKAGING: Premeasured powder packaged in metal container.
    Premeasured liquid in polyurethane
(g) NUMBER OF COMPONENTS: 2
(h) GLOSS (ASTM D 523): container flat
(i) STORAGE REQUIREMENTS: TEMP. MIN. N/A MAX. 60°C
(j) VOLATILE ORGANIC COMPOUND (EPA TEST METHOD 24):
(k) WEIGHT OF DRY FILM (WEIGHT PER AREA AT A GIVEN THICKNESS):

SPECIAL SAFETY PRECAUTIONS:
Solvents contained in this coating are extremely flammable and may cause irritation. Use extreme caution if applying in enclosed areas. Keep away from heat and sparks or open flame. Always use with adequate ventilation. See U.S. Department of Labor Material Safety Data Sheet for additional information.

IV. SURFACE PREPARATION MINIMUM REQUIREMENTS (USE SPECIFIC STANDARD NUMBERS):
(a) INITIAL - Commercial Blast, SSPC-SP 6
(b) TOUCH-UP - Power Tool Clean, SSPC-SP 3
(c) PROFILE INCLUDE METHOD USED - MIN. 25 mic Max. 90 mic
   Gardner Model 123 Profilometer
(d) SPECIAL INSTRUCTIONS -
   Do not use power wire brush for power tool cleaning.
(e) PRIMER REQUIREMENTS (IF APPLICABLE): None

OVER
V. MIXING PROCEDURE:

(a) MIXING RATIO BY WEIGHT - 1kg component A to 1kg of component B
BY VOLUME - 1 part component A to 1 part component B

(b) INDUCTION TIME - 30 minutes

(c) RECOMMENDED SOLVENT - THINNING -

- CONFINED AREAS - #1 Solvent
- NON-CONFINED AREAS - #2 Solvent
- CLEAN UP - 1 part xylene to 1 part MIBK

(d) THINNING REQUIREMENTS (RATIO) - 25% maximum

(e) POT LIFE -

<table>
<thead>
<tr>
<th>Hr(s)</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>24</td>
<td>27</td>
</tr>
</tbody>
</table>

(f) SPECIAL INSTRUCTIONS -

Keep mixture under constant agitation during application. Strain mixture through #30 mesh strainer.

VI. APPLICATION:

(a) ENVIRONMENTAL LIMITATIONS -

<table>
<thead>
<tr>
<th>TEMP.</th>
<th>MIN. 10°C</th>
<th>MAX. 80°C</th>
</tr>
</thead>
</table>

*% RELATIVE HUMIDITY:

<table>
<thead>
<tr>
<th>MIN.</th>
<th>50%</th>
<th>MAX. 90%</th>
</tr>
</thead>
</table>

(b) FILM THICKNESS (SSPC PA2-73T) - WET MIN. 200 | WET MAX. 860
DRY MIN. 100 | DRY MAX. 172

(c) DRY TIMES (ASTM D 1650) - RECOAT

<table>
<thead>
<tr>
<th>MIN.</th>
<th>24 Hr(s)</th>
<th>27 °C</th>
<th>50% R.H.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN.</td>
<td>48 Hr(s)</td>
<td>16 °C</td>
<td>50% R.H.</td>
</tr>
<tr>
<td>MIN.</td>
<td>72 Hr(s)</td>
<td>10 °C</td>
<td>50% R.H.</td>
</tr>
</tbody>
</table>

MAX. 6 mo. Hr(s) @ 50% R.H.

TO HANDLE

<table>
<thead>
<tr>
<th>MIN.</th>
<th>4.0 Hr(s)</th>
<th>10 °C</th>
<th>50% R.H.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN.</td>
<td>24 Hr(s)</td>
<td>16 °C</td>
<td>50% R.H.</td>
</tr>
<tr>
<td>MIN.</td>
<td>72 Hr(s)</td>
<td>10 °C</td>
<td>50% R.H.</td>
</tr>
</tbody>
</table>

FOR IMMERSION

<table>
<thead>
<tr>
<th>MIN.</th>
<th>72 Hr(s)</th>
<th>27 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN.</td>
<td>144 Hr(s)</td>
<td>16 °C</td>
</tr>
<tr>
<td>MIN.</td>
<td>288 Hr(s)</td>
<td></td>
</tr>
</tbody>
</table>

MAX. N.A Hr(s) @ 50% R.H.

(d) EQUIPMENT REQUIREMENTS (INCLUDE PREFERRED, SUITABLE AND NOT SUITABLE REQUIREMENTS).

Conventional spray-agitated pot, external mix spray gun with 1.8m/m tip combination
Airless spray - 8m/m with 80-125 bar fluid pressure
Brush and roller - Minor touch-up only

(e) SPECIAL INSTRUCTIONS - This material is to be applied in three coats using alternate color for each coat.

* CAUTION SHOULD BE TAKEN THAT SURFACE TEMPERATURE IS AT LEAST 3°C ABOVE DEW POINT.
Standard Specification for Gage Piping Assemblies

This standard is issued under the fixed designation F 721; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers details of gage piping assemblies for pressure gages with optional provisions for additional gages, pressure switches, transmitters, and so forth, for use with steam, steam drains, feed water, condensate, fresh water, salt water, compressed air, fuel oil, and lubricating oil systems.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 105/A105M Specification for Carbon Steel Forgings for Piping Applications
A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A 108 Specification for Steel Bars, Carbon, Cold Finished, Standard Quality
A 182/A182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 276 Specification for Stainless Steel Bars and Shapes
A 335/A335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
B 16 Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines
B 61 Specification for Steam or Valve Bronze Castings
B 62 Specification for Composition Bronze or Ounce Metal Castings
B 75 Specification for Seamless Copper Tube
B 124 Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
B 453 Specification for Copper-Zinc-Lead Alloy (Leaded-Brass) Rod
B 466/B 466M Specification for Seamless Copper-Nickel Pipe and Tube

2.2 American National Standard Institute Standards:
B16.11 Forged Steel Fittings, Socket Weld, and Threaded
B16.15 Cast Bronze Threaded Fittings

2.3 Federal Specifications:
QQ-S-637 Steel Bar, Carbon, Cold Finished (Standard Quality, Free Machining)
QQ-S-763 Steel Bars, Wire, Shapes, and Forgings, Corrosion-Resisting

3. List of Assemblies

3.1 This specification incorporates 13 gage piping assemblies as described in Table 1.

4. General Requirements and Guidelines

4.1 Fig. 1 shows a typical piping assembly for bottom-connected gages and Fig. 2 a typical piping assembly for back-connected gages.

4.2 A siphon shall be used as shown in all gage applications for steam systems to maintain a protective water seal between the gage and the steam supply.

4.3 Each assembly includes a test connection beyond the gage valve which consists of a tee with a 1/4-in. NPT threaded plug in the branch. The plug is removable for the purpose of installing a test gage for calibration. As an alternative, a gage valve that incorporates a built-in test connection integral with the valve may be substituted for the gage valve and test tee.

4.4 Root connections should be kept to a minimum by connecting other instruments at the tee between the root and gage valves. There is no limit to the number of dead-end-type instruments that can be served from a single root connection. However, each instrument should have its own shutoff valve and, if desired, a test tee may be fitted at each instrument.

4.5 Two shutoff valves are generally used in each assembly, a root valve and a gage cutout valve. The gage valve may be

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.
2 Annual Book of ASTM Standards, Vol 01.01.
3 Annual Book of ASTM Standards, Vol 01.05.
4 Annual Book of ASTM Standards, Vol 01.03.
5 Annual Book of ASTM Standards, Vol 02.01.
6 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
7 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
eliminated and a single shutoff valve may serve as both a root and gage valve provided the gage is within 6 ft (1.8 m) of the root connection and readily accessible and the single shutoff valve is fitted within 12 in. (300 mm) of the root connection.

4.6 Pulsation dampeners are shown for certain assemblies between the test tee and gage and should be used in other assemblies in which the gage may be subjected to pulsating pressures, as from a reciprocating pump, air compressor, quick-acting solenoid valves, and high-frequency vibrations of high-pressure feed pumps.

4.7 Isolation devices (diaphragm seals) should be installed where system fluid viscosity and fuel isolation is a consideration.

5. Services, Pressure/Temperature Limitations, and Material

5.1 Service and pressure/temperature limitations for each assembly are listed in Table 1 and materials are listed in Table 2 and Table 3. Other services, pressure/temperatures, and materials may be used provided the materials selected are compatible with the intended system media, and the pressure/temperature limitations do not exceed the limitations of the material chosen.
### TABLE 2 Material List

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Nominal Size, in.</th>
<th>Description</th>
<th>Material</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1½ NPS by 1½ FPT</td>
<td>Globe valve, thread by socket weld</td>
<td>alloy steel (Cr-Mo)</td>
<td>ASTM A 182/A 182M, F 11</td>
</tr>
<tr>
<td>2</td>
<td>¾ FPT</td>
<td>Globe needle valve, thread, bar stock type</td>
<td>carbon steel</td>
<td>QQ-S-637, Grades 1213 and 1215</td>
</tr>
<tr>
<td>3</td>
<td>¾ NPS by ¾ FPT</td>
<td>Globe needle valve, thread by socket weld, bar stock type</td>
<td>carbon steel</td>
<td>QQ-S-637, 1213 and 1215</td>
</tr>
<tr>
<td>4</td>
<td>½ NPS by ½ FPT</td>
<td>Globe needle valve, thread by socket weld, bar stock type</td>
<td>carbon steel</td>
<td>QQ-S-637, 1213 and 1215</td>
</tr>
<tr>
<td>5</td>
<td>¾ NPS</td>
<td>Globe needle valve, socket weld, bar stock type</td>
<td>carbon steel</td>
<td>QQ-S-637, 1213 and 1215</td>
</tr>
<tr>
<td>6</td>
<td>¾ NPS by ¾ FPT</td>
<td>Globe needle valve, thread by socket weld, bar stock type</td>
<td>316 stainless steel</td>
<td>QQ-S-763</td>
</tr>
<tr>
<td>7</td>
<td>¼ FPT</td>
<td>Globe needle valve, thread, bar stock type</td>
<td>316 stainless steel</td>
<td>QQ-S-763</td>
</tr>
<tr>
<td>8</td>
<td>¼ NPS by ¼ FPT</td>
<td>Globe needle valve, thread by silbraze</td>
<td>bronze</td>
<td>ASTM B 61</td>
</tr>
<tr>
<td>9</td>
<td>¼ FPT</td>
<td>Globe needle valve, thread</td>
<td>bronze</td>
<td>ASTM B 61</td>
</tr>
<tr>
<td>10</td>
<td>½ NPS</td>
<td>Pipe, Schedule 80</td>
<td>alloy steel (Cr-Mo)</td>
<td>ASTM A 355, P11</td>
</tr>
<tr>
<td>11</td>
<td>¼ NPS</td>
<td>Pipe, Schedule 80</td>
<td>carbon steel</td>
<td>ASTM A 106, Grade B</td>
</tr>
<tr>
<td>12</td>
<td>½ NPS</td>
<td>Pipe, Schedule 80</td>
<td>carbon steel</td>
<td>ASTM A 106, Grade B</td>
</tr>
<tr>
<td>13</td>
<td>¼ NPS</td>
<td>Pipe, Schedule 80</td>
<td>copper-nickel 90-10</td>
<td>ASTM B 466/B 466M, Alloy 706</td>
</tr>
<tr>
<td>14</td>
<td>¼ OD</td>
<td>Tubing, 0.065-in. (1.65-mm) wall</td>
<td>carbon steel</td>
<td>ASTM A 106, Grade B</td>
</tr>
<tr>
<td>15</td>
<td>¼ OD</td>
<td>Tubing, 0.035-in. (0.89-mm) wall</td>
<td>copper</td>
<td>ASTM B 75</td>
</tr>
<tr>
<td>16</td>
<td>¼ OD by ½ MPT</td>
<td>Connector, tube by thread, compression type</td>
<td>carbon steel</td>
<td>ASTM A 108, Grade 12L14</td>
</tr>
<tr>
<td>17</td>
<td>½ by ¼ NPS</td>
<td>Reducing insert, socket weld</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>18</td>
<td>¼ FPT</td>
<td>Tee, thread</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>19</td>
<td>¼ MPT</td>
<td>Plug, thread</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>20</td>
<td>¼ NPS</td>
<td>Tee, socket weld</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>21</td>
<td>¼ NPS</td>
<td>Union, socket weld</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>22</td>
<td>¼ NPS</td>
<td>Coupling</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>23</td>
<td>¼ OD by ¼ MPT</td>
<td>Connector, tube by thread, compression type</td>
<td>carbon steel</td>
<td>ASTM A 106, Grade 12L14</td>
</tr>
<tr>
<td>24</td>
<td>¼ OD</td>
<td>Tee, tube, compression type</td>
<td>carbon steel</td>
<td>ASTM A 576, Grade 12L14</td>
</tr>
<tr>
<td>25</td>
<td>¼ OD</td>
<td>Union, tube, compression type</td>
<td>carbon steel</td>
<td>ASTM A 106, Grade 12L14</td>
</tr>
<tr>
<td>26</td>
<td>¼ FPT</td>
<td>Tee thread</td>
<td>bronze</td>
<td>ASTM B 62, ANSI B16.15</td>
</tr>
<tr>
<td>27</td>
<td>¼ MPT</td>
<td>Plug, thread</td>
<td>bronze</td>
<td>ASTM B 62, ANSI B16.15</td>
</tr>
<tr>
<td>28</td>
<td>¼ OD</td>
<td>Union, tube, compression type</td>
<td>brass</td>
<td>ASTM B 453, Alloy 345; ASTM B 16, Alloy 360</td>
</tr>
<tr>
<td>29</td>
<td>¼ OD by ¼ MPT</td>
<td>Connector, tube by thread, compression type</td>
<td>brass</td>
<td>ASTM B 453, Alloy 345; ASTM B 16, Alloy 360</td>
</tr>
<tr>
<td>30</td>
<td>¼ OD</td>
<td>Tee, tube, compression type</td>
<td>brass</td>
<td>ASTM B 124, Alloy 377</td>
</tr>
<tr>
<td>31</td>
<td>¼ OD by ¼ MPT</td>
<td>Connector, tube by thread, compression type</td>
<td>316 stainless steel</td>
<td>ASTM A 276</td>
</tr>
<tr>
<td>32</td>
<td>¼ OD</td>
<td>Tee, tube, compression type</td>
<td>316 stainless steel</td>
<td>ASTM A 276</td>
</tr>
<tr>
<td>33</td>
<td>¼ MPT by ¼ FPT</td>
<td>Pulsation dampener, thread</td>
<td>316 stainless steel</td>
<td>commercial</td>
</tr>
<tr>
<td>34</td>
<td>¼ FPT</td>
<td>90° elbow, thread</td>
<td>carbon steel</td>
<td>ASTM A 105/A 105M, ANSI B16.11</td>
</tr>
<tr>
<td>35</td>
<td>¼ FPT</td>
<td>90° elbow, thread</td>
<td>bronze</td>
<td>ASTM B 62, ANSI B16.15</td>
</tr>
<tr>
<td>36</td>
<td>¼ OD</td>
<td>Union, tube, compression type</td>
<td>316 stainless steel</td>
<td>ASTM A 276</td>
</tr>
</tbody>
</table>

### TABLE 3 Material Part Numbers Used in Gage Piping Assemblies<sup>a</sup><sup>b</sup>

<table>
<thead>
<tr>
<th>Component Identification Letter (See Fig. 1 for Bottom-Connected Gages or Fig. 2 for Back-Connected Gages)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A B C D E F G H J K L M N&lt;sup&gt;c&lt;/sup&gt; P&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>1 ... 10 1 16 14 24 25 2 18 19 ... ... 34 11</td>
</tr>
<tr>
<td>2 ... 12 4 16 14 24 25 2 18 19 ... ... 34 11</td>
</tr>
<tr>
<td>3 ... 11 3 23 14 24 25 2 18 19 ... ... 34 11</td>
</tr>
<tr>
<td>4 ... 11 3 23 15 24 25 2 26 27 ... ... 34 11</td>
</tr>
<tr>
<td>5 ... 11 3 23 14 24 25 2 18 19 33 ... 34 11</td>
</tr>
<tr>
<td>6 ... 11 3 23 15 24 25 2 26 27 ... ... 34 11</td>
</tr>
<tr>
<td>7 ... 11 3 23 14 24 25 2 18 19 33 ... 34 11</td>
</tr>
<tr>
<td>8 ... 11 3 23 15 24 25 2 26 27 33 ... ... 34 13</td>
</tr>
<tr>
<td>9 ... 11 3 23 15 24 25 2 26 27 ... ... 35 13</td>
</tr>
<tr>
<td>10 ... 13 6 31 15 32 36 7 26 27 ... ... 35 13</td>
</tr>
<tr>
<td>11 ... 11 8 31 15 32 36 9 26 27 ... ... 35 13</td>
</tr>
<tr>
<td>12 ... 11 5 ... 11 20 22 5 18 19 ... 21 34 11</td>
</tr>
<tr>
<td>13 ... 11 3 23 14 24 25 2 18 19 ... ... 34 11</td>
</tr>
</tbody>
</table>

<sup>a</sup>For description of material part numbers see Table 2.<br><sup>b</sup>For service and pressure/temperature limitations of each assembly see Table 1.<br><sup>c</sup>“N” and “P” are for use with back-connected gages only.
Standard Specification for
Welded Joints for Shipboard Piping Systems

1. Scope
1.1 This specification covers typical details of welded joints commonly used in shipboard piping systems. These joints and other joints may be used provided the welding procedures used have been qualified in accordance with the applicable regulatory rules and regulations.
1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents
2.1 Federal Standards:
Code of Federal Regulations Title 46, Shipping, Parts 30 to 40
Code of Federal Regulations Title 46, Shipping, Parts 41 to 69
Code of Federal Regulations Title 46, Shipping, Parts 140 to 149
Rules for Building and Classing Steel Vessels

3. Application, Service, Limitations, and List of Weld Joint Details
3.1 Details of welded joints, including application, service, and limitation notes, are provided in the appropriate figures, as follows:
3.1.1 Butt-Welded Joints for Pipes, Valves, Fittings, and Flanges:
Fig. 1 Butt Joint, Square
Fig. 2 Butt Joint, V-Grooved
Fig. 3 Butt Joint, V-Grooved, Welded Both Sides
Fig. 4 Butt Joint, Double V-Grooved, Welded Both Sides
Fig. 5 Butt Joint, Compound Bevel V-Grooved, Welded Both Sides
Fig. 6 Butt Joint, V-Grooved, Miter Type
Fig. 7 Butt Joint, V-Grooved, Welded with Bevel End-Type Backing Ring
Fig. 8 Butt Joint, Compound Bevel V-Grooved, Welded with Bevel End-Type Backing Ring
Fig. 9 Butt Joint, V-Grooved Welded with Bevel End Lug-Type Backing Ring
Fig. 10 Butt Joint, V-Grooved, Welded with Square End-Type Backing Ring
Fig. 11 Butt Joint, V-Grooved, Welded with Consumable Insert Ring
Fig. 12 Butt Joint, Compound Bevel V-Grooved, Welded with Consumable Insert Ring
Fig. 13 Butt Joint, U-Grooved, Welded with Consumable Insert Ring
Fig. 14 Butt Joint, V-Grooved, Welded with Consumable Insert Ring
Fig. 15 Butt Joint, Socket Weld to Socket Weld Valve, Fitting or Flange Welded on Pipe Nipple
Fig. 16 Butt Joint, Transition between Unequal Inside and Outside Diameter Components
Fig. 17 Fillet Welded Sleeve-Type Pipe Coupling
Fig. 18 Fillet Welded Socket Weld Fitting or Valve
Fig. 19 Fillet Welded Socket Weld-Flange
Fig. 20 Double Fillet Welded Slip-On Flange (Forged)
Fig. 21 Double Fillet Welded Slip-On Flange (Plate Type)
Fig. 22 Fillet Welded Slip-On Flange (Plate Type), Single Bevel
3.1.2 Fillet Welded Joints for Valves, Fittings, and Flanges:
Fig. 23 Fillet Welded Internal Root Connection
Fig. 24 Fillet Welded External Root Connection
Fig. 25 Fillet Reinforced External Root Connection Single Bevel
Fig. 26 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides
Fig. 27 Fillet Reinforced External Root Connection, Single Bevel, Welded with Square End Backing Ring
Fig. 28 Fillet Reinforced Internal Root Connection, Single Bevel, Welded with Square End Backing Ring
3.1.3 Fabricated Joints:
Fig. 29 Fillet Welded Box Joint
Fig. 30 Fillet Welded Internal Root Connection
Fig. 31 Fillet Welded External Root Connection
Fig. 32 Fillet Reinforced External Root Connection Single Bevel
Fig. 33 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides
Fig. 34 Fillet Reinforced External Root Connection, Single Bevel, Welded with Square End Backing Ring
Fig. 35 Fillet Reinforced Internal Root Connection, Single Bevel, Welded with Square End Backing Ring
3.1.4 Outlet and Boss Connections:
4. Piping Classifications and Butt Weld Reinforcements

4.1 Piping classifications in accordance with Subpart 56.04 of USCG Regulations apply to this specification. For definitions of ABS Group I and II Pipe Connections, see ABS Rules, Section 30, Paragraph 30.13.

4.2 Maximum thickness of butt weld reinforcements in accordance with Subpart 56.70, Table 56.70-15, of USCG Regulations are listed in Table 1.

5. Keywords

5.1 backing ring pipe welds; boss connections; flange welds; miter joint weld; pipe welds; root connections; sleeve pipe welds; socket welds; welded joints

### TABLE 1 Maximum Butt Weld Reinforcement, in. (mm)

<table>
<thead>
<tr>
<th>Nominal Wall Thickness of Pipe or Tube, in.</th>
<th>0 to 350 (−18 to 177) °F (°C)</th>
<th>350 to 750 (177 to 399) °F (°C)</th>
<th>Above 750 (399) °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to ¼</td>
<td>3/32 (2)</td>
<td>3/32 (2)</td>
<td>1/16 (2)</td>
</tr>
<tr>
<td>Over ¼ to ½</td>
<td>½ (6)</td>
<td>½ (6)</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over ½ to 1</td>
<td>¾ (5)</td>
<td>¾ (5)</td>
<td>5/32 (4)</td>
</tr>
<tr>
<td>Over 1 to 2</td>
<td>1/8 (3)</td>
<td>1/8 (3)</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 2 greater of ⅛ (6) or ⅛ the width of the weld</td>
<td>⅛ (6)</td>
<td>⅛ (6)</td>
<td>⅛ (6)</td>
</tr>
</tbody>
</table>

Application—Class II piping

Systems or Service—For services such as gravity drains (including plumbing), vents, and overflows.

Remarks—1. Root of weld need not be ground.

FIG. 1 Butt Joint, Square
Application—Class II piping
System or Service—All provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. For services such as vents, overflows, and gravity drains (including plumbing) the root of the weld need not be ground.

FIG. 2 Butt Joint, V-Grooved

Application—Class I and II piping above 2-in. NPS
System or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The “L” dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 4 Butt Joint, Double V-Grooved, Welded Both Sides

Application—Class I and II piping above 2-in. NPS
System or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The “L” dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 5 Butt Joint, Compound Bevel V-Grooved, Welded Both Sides
Application—Class II piping where use will not cause objectionable pressure drop or turbulence.

System or Service—All provided root of weld is visually inspected where possible to ensure complete weld penetration.

Remarks—1. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground. 2. Miter segments shall be designed in accordance with ANSI B31.1, paragraph 104.33, and 46 CFR 56.07-16(f).

FIG. 6 Butt Joint, V-Grooved, Miter Type

$\frac{1}{16}$ in. = 2 mm

$\frac{1}{8}$ in. = 3 mm

$\frac{3}{16}$ in. = 5 mm

$\frac{3}{8}$ in. = 10 mm

$\frac{1}{4}$ in. = 19 mm

$\frac{7}{8}$ in. = 22 mm

Application—Class I and II piping

System or Service—All, except as noted in remarks

Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication. 2. When used in the following services, backing rings shall be removed.

(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.

(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.

(C) Central hydraulic systems.

FIG. 7 Butt Joint, V-Grooved, Welded with Bevel End-Type Backing Ring

$\frac{1}{16}$ in. = 2 mm

$\frac{1}{8}$ in. = 3 mm

$\frac{3}{16}$ in. = 5 mm

$\frac{3}{8}$ in. = 10 mm

$\frac{1}{4}$ in. = 19 mm

$\frac{7}{8}$ in. = 22 mm

Application—Class I and II piping

System or Service—All, except as noted in remarks

Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication. 2. When used in the following services, backing rings shall be removed.

(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.

(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.

(C) Central hydraulic systems.

FIG. 8 Butt Joint, Compound Bevel V-Grooved, Welded with Bevel End-Type Backing Ring

$\frac{1}{16}$ in. = 2 mm

$\frac{1}{8}$ in. = 3 mm

$\frac{3}{16}$ in. = 5 mm

$\frac{3}{8}$ in. = 10 mm

$\frac{1}{4}$ in. = 19 mm

$\frac{7}{8}$ in. = 22 mm

Application—Class I and II piping

System or Service—All, except as noted in remarks

Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication. 2. When used in the following services, backing rings shall be removed.

(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.

(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.

(C) Central hydraulic systems.

FIG. 9 Butt Joint, V-Grooved Welded with Bevel End Lug-Type Backing Ring

$\frac{1}{16}$ in. = 2 mm

$\frac{1}{8}$ in. = 3 mm

$\frac{3}{16}$ in. = 5 mm

$\frac{3}{8}$ in. = 10 mm

$\frac{1}{4}$ in. = 19 mm

$\frac{7}{8}$ in. = 22 mm

Application—Class I and II piping

System or Service—All, except as noted in remarks

Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication. 2. When used in the following services, backing rings shall be removed.

(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.

(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.

(C) Central hydraulic systems.
Application—Class I and II piping
System or Service—All
Remarks—1. After welding, backing ring shall be machined flush with inside diameter of pipe or fitting.

**FIG. 10** Butt Joint, V-Grooved, Welded with Square End-Type Backing Ring

<table>
<thead>
<tr>
<th>in.</th>
<th>1/64</th>
<th>1/32</th>
<th>1/16</th>
<th>5/32</th>
<th>7/32</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>19</td>
<td>22</td>
</tr>
</tbody>
</table>

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

**FIG. 11** Butt Joint, V-Grooved, Welded with Consumable Insert Ring

<table>
<thead>
<tr>
<th>in.</th>
<th>1/64</th>
<th>1/32</th>
<th>1/16</th>
<th>3/32</th>
<th>7/32</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>0.4</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>19</td>
</tr>
</tbody>
</table>

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/32 in. (1 mm).
2. Consumable insert ring shall be centered before welding.

**FIG. 12** Butt Joint, Compound Bevel V-Grooved, Welded with Consumable Insert Ring

<table>
<thead>
<tr>
<th>in.</th>
<th>1/64</th>
<th>1/32</th>
<th>1/16</th>
<th>3/32</th>
<th>7/32</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>0.4</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>19</td>
</tr>
</tbody>
</table>

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/32 in. (1 mm).
2. Consumable insert ring shall be centered before welding.

**FIG. 13** Butt Joint, U-Grooved, Welded with Consumable Insert Ring

<table>
<thead>
<tr>
<th>in.</th>
<th>1/64</th>
<th>1/32</th>
<th>1/16</th>
<th>3/32</th>
<th>7/32</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>0.4</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>19</td>
</tr>
</tbody>
</table>

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/32 in. (1 mm).
2. Consumable insert ring shall be centered before welding.

**FIG. 14** Butt Joint, V-Grooved, Welded with Consumable Insert Ring

<table>
<thead>
<tr>
<th>in.</th>
<th>1/64</th>
<th>1/32</th>
<th>1/16</th>
<th>3/32</th>
<th>7/32</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>0.4</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>19</td>
</tr>
</tbody>
</table>
1/16 in. = 2 mm
1/4 in. = 6 mm
3/8 in. = 10 mm

Application—Fittings: See Fig. 18. Flanges: See Fig. 19.
System or Service—See Fig. 18 and Fig. 19.
Remarks—1. Size of weld shall be equal to or greater than "T."
2. For Class I piping, depth of insertion of the pipe nipple into the fitting shall not be less than 3/8 in. (10 mm).
3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 15 Butt Joint, Socket Weld to Socket Weld Valve, Fitting or Flange Welded on Pipe Nipple

FIG. 16 Butt Joint, Transition Between Unequal Inside and Outside Diameter Components

Application—Class I piping 3-in. NPS max where not subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.
System or Service—All
Remarks—1. Size of weld shall be 1 1/4 T min but not less than 1/8 in. (3 mm).
2. For Class I piping, depth of insertion of pipe, tube, or fitting in sleeve shall not be less than 3/8 in. (10 mm).
3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.
4. For Class I piping, the inside diameter of the sleeve shall not exceed the outside diameter of the pipe, tube, or fitting by more than 0.080 in. (2.03 mm).
5. Couplings may be used with flat or beveled end pipes and fitting.

FIG. 17 Fillet Welded Sleeve-Type Pipe Coupling

Application—Class I piping 3-in. NPS max where not subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.
System or Service—All, except socket welds shall not be used where severe erosion or crevice corrosion is expected to occur.
Remarks—1. Size of weld shall be 1 1/4 T min but not less than 1/8 in. (3 mm).
2. For Class I piping, depth of insertion of pipe or tube into the fitting shall not be less than 3/8 in. (10 mm).
3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 18 Fillet Welded Socket Weld Fitting or Valve
Application—Class I piping 3-in. NPS max for 600# and lower classes and 2¼-in. NPS for 900 and 1500# classes. 3-in. size not permitted where subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

System or Service—All, except socket welds shall not be used where severe erosion or crevice corrosion is expected to occur.

Remarks—1. Size of Weld W1 shall be 1.4 T min. for Class II piping, size of weld may be limited to $\frac{17}{32}$ in. (13 mm) max.
2. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 19 Fillet Welded Socket Weld Flange

Application—Class II piping not exceeding 150 psi (1034 kPa) or 450°F (232°C)

System or Service—All

Remarks—1. Size of Weld 8a W1 shall be 1.4 "T" min but may be limited to $\frac{17}{32}$ in. (13 mm).
2. Size of Weld W2 shall be equal to "T" or $\frac{1}{4}$ in. (6 mm), whichever is smaller.
3. Distance X shall be T plus $\frac{1}{16}$ in. (2 mm) min but may be limited to $\frac{3}{8}$ in. (10 mm).

FIG. 20 Double Fillet Welded Slip-on Flange (Forged)

Application—Class I and II piping not to exceed the service pressure temperature ratings for the 300# and lower classes. Slip-on flanges shall not be used on Class I piping where subject to full radiography by 46 CFR Table 56.95-10.

System or Service—All

Remarks—1. Size of Weld W1 shall be 1.4 T min. for Class II piping, size of weld may be limited to $\frac{17}{32}$ in. (13 mm) max.
2. Size of Weld W2 shall be equal to "T" or $\frac{1}{4}$ in. (6 mm), whichever is smaller.
3. Dimension X shall be equal to T plus $\frac{1}{16}$ in. (2 mm) min. for Class II piping. Dimension X may be limited to $\frac{3}{8}$ in. (10 mm).

FIG. 21 Double Fillet Welded Slip-on Flange (Plate Type)
Application—Class II piping not exceeding 150 psi (1034 kPa) or 650°F (343°C)
System or Service—All
Remarks—1. Size of Weld W1 shall be 1.4 "T" min but may be limited to 17/32 in. (13 mm).
2. Size of Weld W2 shall be equal to "T" or 1/4 in. (6 mm), whichever is smaller.
3. Distance X shall be "T" plus 1/8 in. (2 mm) min but may be limited to 3/8 in. (10 mm).

FIG. 22 Fillet Welded Slip-on Flange (Plate-Type) Single Bevel

Application—Class II piping above 2-in. NPS.
System or Service—All, provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1/4 in. (6 mm), whichever is smaller.
2. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.

FIG. 23 Fillet Welded Internal Root Connection

Application—Class II piping in Class II piping
System or Service—For services such as vents, overflows, and gravity drains (including plumbing).
Remarks—1. Size of weld shall be T min.
Application—Class I and II piping above 2-in. NPS
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or ¼ in. (6 mm), whichever is smaller.
2. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
3. The “L” dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 26 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides

Application—Class I and II piping.
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or ¼ in. (6 mm), whichever is smaller.
2. After welding, backing ring shall be machined flush with inside diameter of pipe.

FIG. 27 Fillet Reinforced External Root Conn, Single Bevel, Welded with Square End Backing Ring

Application—Class I and II piping.
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

FIG. 28 Fillet Reinforced Internal Root Conn, Single Bevel, Welded With Square End Backing Ring

Application—Class I and II piping.
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

FIG. 29 Fillet Reinforced Boss Conn Without Pilot, Single Bevel
Application—Class I and II piping.
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 1/4 in. (6 mm).
2. Pilot hole shall be 1/32 in. (1 mm) larger than pilot diameter.
3. Final bore after welding shall be a minimum of 1/8 in. (3 mm) larger than pilot diameter.

**FIG. 30 Fillet Reinforced Boss Conn with Pilot, Single Bevel**

Application—Class II piping.
System or Service—All, provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 1/4 in. (6 mm).
2. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.

**FIG. 32 Fillet Reinforced External Root Conn, Single Bevel with Integrally Reinforced Outlet**

Application—Class I and II piping.
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 1/4 in. (6 mm).
2. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.

**FIG. 33 Fillet Reinforced External Root Conn Welded Both Sides, Single Bevel with Integrally Reinforced Outlet**

Application—Class I and II piping.
System or Service—All.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 1/4 in. (6 mm).
2. Final bore after welding shall be a minimum of 1/8 in. (3 mm) larger than pilot diameter.

**FIG. 31 Fillet Reinforced Boss Conn (Couplet) with Integral Backing Ring**
Standard Specification for Wildcats, Ship Anchor Chain

This standard is issued under the fixed designation F 765; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers wildcats as used in windlasses to haul in and pay out anchor chain on board ships. An associated chain stopper is used to secure the chain while the ship is anchored, or the anchor is housed.

1.2 Wildcats are of the five whelp type for use with stud link anchor chain conforming to the American Bureau of Shipping Grades 1, 2, and 3. Wildcat dimensions are provided for chains in integral 1/8-in. (3-mm) steps, ranging in size from 3/4 to 4 1/8 in. (19 to 104 mm). Wildcat dimensions for chains in intermediate 1/16-in. (1.5-mm) steps are not provided, but wildcats in these sizes are permitted within the scope of this specification.

1.3 Wildcats are configured to pass detachable links oriented parallel or perpendicular to the wildcat shaft centerline.

1.4 The values stated in inch-pound units are to be regarded as the standard. This specification is for use with anchor chain that is measured in inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:
A 27/A 27M Specification for Steel Castings, Carbon, for General Application
A 36/A 36M Specification for Structural Steel
A 148/A 148M Specification for Steel Castings, High-Strength, for Structural Purposes
E 10 Test Method for Brinell Hardness of Metallic Materials

2.2 Other Documents:
American Bureau of Shipping, Rules for Building and Classing Steel Vessels, Section 43.11 Equipment
American Welding Society Structural Welding Code, Chapter D1.1

3. Classification

3.1 The size of the wildcat is identified by the chain size.

3.2 Wildcats are furnished in four types as follows:

3.2.1 Type I—Fabricated from structural steel plate for flanges, hubs, whelps, and chain pockets, joined by electric welding. Surface hardness is approximately 150 HB.

3.2.2 Type II—Fabricated from structural steel plate for flanges, hubs, and chain pockets; and high-strength steel castings for whelps, joined by electric welding. Surface hardness is approximately 150 HB for flanges and hubs and 300 HB for whelps.

3.2.3 Type III—Cast from medium-strength carbon steel castings to provide a surface hardness of approximately 150 HB.

3.2.4 Type IV—Cast from high-strength steel castings to provide a surface hardness of approximately 300 HB.

4. Descriptions of Terms

4.1 chain groove—circumferential groove at the chain centerline to provide clearance for links passing normal to the wildcat shaft centerline.

4.2 chain pockets—recesses between the flanges and whelps into which links with flat side orientated parallel to the wildcat shaft centering lay.

4.3 detachable link—a “C” shaped link, closed by means of a pair of closing pieces and a taper pin, and used to join anchor chain lengths and appendages into a continuous length aboard ship.

4.4 flanges—circumferential rims on the outside of the whelps, chain pockets, and chain groove.

4.5 link grip—the inside dimension of a chain link representing the effective length of a chain link in an assembled chain. Generally four times the nominal size of a stud link anchor chain, see Fig. 1.

4.6 whelps—protrusions on the inside of the flanges of the wildcat that resemble gear teeth and of such shape and
dimensions so as to follow the path of the chain, as it enters and leaves the wildcat. Faces of protrusions are separated by the chain groove to permit links with the flat side normal to the wildcat shaft centerline to pass, but blocking links with the flat side oriented parallel to the wildcat shaft centerline.

4.7 **wildcat**—a rotating member specially contoured to receive assembled chain links and connecting links around the circumference of the member and of suitable strength to impart motion to the chain when rotated.

5. **Ordering Information**

5.1 Orders for wildcats under this specification shall include the following:

5.1.1 Quantity (number),
5.1.2 Size (chain size),
5.1.3 ASTM designation and date of issue,
5.1.4 Type (I, II, III, or IV),
5.1.5 Size, grade, and type of chain,
5.1.6 Availability of assembled chain and detachable link to be furnished by the purchaser for test (see Section 9),
5.1.7 As-cast or machined dimensions for wildcat bore, hub width, and outside boss diameter, and
5.1.8 Marking (shipping).

6. **Materials and Manufacture**

6.1 Material for Type I wildcats shall conform to Specification A 36/A 36M for flanges, hubs, whelps, and chain pockets, joined by electric welding in accordance with AWS, structural welding code Chapter D1.1. Type I wildcats in sizes 2 in. and larger shall be stress-relieved. Material for Type II wildcats shall conform to Specification A 36/A 36M for flanges and hubs, and chain pockets, and Specification A 148/A 148M for whelps, joined by electric welding in accordance with AWS, Structural Welding Code, Chapter D1.1, stress-relieved and heat-treated. Material for Type III wildcats shall conform to Specification A 27/A 27M, Grade 70-40, quenched and tempered. Material for Type IV wildcats shall conform to Specification A 148/A 148M, Grade 150-125, quenched and tempered.

6.2 The manufacturer’s name or identification mark, chain size, and pattern or drawing number shall be cast or stamped on the wildcat, using minimum 3/4 -in. (19-mm) size characters. The marking shall not appear on a wearing surface and shall be visible on an assembled windlass.

7. **Dimensions**

7.1 Wildcat must be fitted to the sample chain, and detachable link (see Section 9). Principal dimensions of Types III and IV wildcats for chains in steps of 1/8 in. (3 mm) are shown for information only in Table 1 and Table 2.

7.2 Dimensions in Table 1 and Table 2 are developed in accordance with the following (see also Fig. 2 and Fig. 3):

7.2.1 Bottom of chain pockets are relieved to clear enlargements occurring at centers of chain links as manufactured.

7.2.2 Each face of the whelp is a partial frustrum of a cone developed so that each link whose plane is parallel to the wildcat shaft centerline will have end play as noted in Table 1 and Table 2. This end play provides clearance between non-bearing side of whelp and the end of the next following link, the centerline plane of which is parallel to the axis of shaft.

7.2.3 The inner surfaces of the chain pockets, that form the flanges of the wildcat, are flat surfaces together forming the frustrums of pentagonal pyramids. The traces of the intersections of these flat surfaces or sides of the frustrums coincide with the centerline of the whelps.

7.2.4 The trace of the intersection of the plane at the bottom of the chain pocket and the side of whelp forms a hyperbolic section of a cone and is therefore a curved line.

7.2.5 Wildcat radii are as follows with all dimensions having the same units:
TABLE 1 Dimensions in Inches of Types III and IV Wildcats for Chains
Size of
Chain
⁄
⁄

34
78

1
11⁄8
11⁄4
13⁄8
11⁄2
15⁄8
13⁄4
17⁄8
2
21⁄8
21⁄4
23⁄8
21⁄2
25⁄8
23⁄4
27⁄8
3
31⁄8
31⁄4
33⁄8
31⁄2
35⁄8
33⁄4
37⁄8
4
41⁄8

R

R1

R2

R3

X

A

B

O

P

S

T

U

4.12
4.80
5.49
6.18
6.87
7.56
8.24
8.93
9.63
10.31
10.99
11.68
12.37
13.05
13.74
14.43
15.11
15.80
16.48
17.17
17.85
18.55
19.23
19.92
20.60
21.30
21.98
22.67

4.09
4.77
5.43
6.12
6.81
7.50
8.18
8.87
9.57
10.25
10.93
11.62
12.31
12.99
13.68
14.37
15.06
15.74
16.42
17.11
17.79
18.49
19.17
19.86
20.54
21.24
21.92
22.61

3.00
3.50
4.00
4.62
5.12
5.62
6.19
6.75
7.31
7.87
8.37
8.87
9.50
10.00
10.62
11.25
11.75
12.25
12.75
13.25
13.87
14.37
15.00
15.50
16.00
16.62
17.00
17.50

4.87
5.68
6.49
7.31
8.12
8.93
9.74
10.55
11.37
12.18
12.99
13.80
14.62
15.42
16.24
17.05
17.86
18.67
19.48
20.30
21.10
21.92
22.73
23.54
24.35
25.17
25.98
26.39

23⁄8
211⁄16
3
31⁄4
31⁄2
33⁄4
41⁄16
43⁄8
411⁄16
5
51⁄4
59⁄16
57⁄8
63⁄16
61⁄2
613⁄16
71⁄8
77⁄16
73⁄4
81⁄16
83⁄8
811⁄16
9
95⁄16
95⁄8
915⁄16
101⁄4
109⁄16

13⁄8
11⁄2
15⁄8
17⁄8
2
21⁄8
21⁄4
21⁄2
23⁄4
27⁄8
3
31⁄8
33⁄8
31⁄2
35⁄8
37⁄8
4
41⁄4
43⁄8
45⁄8
43⁄4
5
51⁄8
53⁄8
55⁄8
53⁄4
6
61⁄4

33⁄8
37⁄8
43⁄8
47⁄8
53⁄8
57⁄8
63⁄8
67⁄8
73⁄8
77⁄8
83⁄8
87⁄8
91⁄4
93⁄4
101⁄4
103⁄4
111⁄4
113⁄4
121⁄4
123⁄4
131⁄4
133⁄4
141⁄4
143⁄4
151⁄4
153⁄4
161⁄4
163⁄4

⁄
⁄
3⁄4
3⁄4
7⁄8
7⁄8
1
11⁄8
11⁄8
11⁄4
11⁄4
13⁄8
13⁄8
11⁄2
11⁄2
15⁄8
13⁄4
13⁄4
17⁄8
17⁄8
17⁄8
2
2
21⁄8
21⁄4
21⁄4
23⁄8
23⁄8

15⁄16
113⁄32
117⁄32
127⁄32
23⁄32
29⁄32
217⁄32
27⁄8
31⁄32
31⁄4
37⁄16
319⁄32
329⁄32
41⁄8
47⁄16
419⁄32
429⁄32
51⁄16
51⁄4
517⁄32
523⁄32
61⁄32
63⁄16
619⁄32
63⁄4
631⁄32
73⁄16
75⁄8

115⁄32
15⁄8
113⁄16
21⁄8
27⁄16
223⁄32
31⁄16
33⁄8
35⁄8
329⁄32
45⁄32
415⁄32
43⁄4
51⁄16
53⁄8
55⁄8
6
63⁄16
61⁄2
625⁄32
71⁄32
75⁄16
79⁄16
731⁄32
81⁄8
87⁄16
813⁄16
91⁄16

221⁄32
33⁄32
31⁄2
331⁄32
47⁄16
47⁄8
53⁄8
527⁄32
61⁄4
623⁄32
71⁄8
75⁄8
731⁄32
87⁄16
815⁄16
93⁄8
915⁄16
105⁄16
1023⁄32
113⁄16
113⁄8
121⁄16
127⁄16
13
137⁄16
137⁄8
145⁄16
1413⁄16

⁄
⁄
1
11⁄8
11⁄4
13⁄8
11⁄2
15⁄8
13⁄4
17⁄8
2
21⁄8
21⁄4
23⁄8
21⁄2
25⁄8
23⁄4
27⁄8
3
31⁄8
31⁄4
33⁄8
31⁄2
35⁄8
33⁄4
37⁄8
4
41⁄8

12
58

V

R4

R5

End Play
of Link

⁄
⁄

2
25⁄16
25⁄8
3
35⁄16
35⁄8
4
45⁄16
45⁄8
415⁄16
51⁄4
55⁄8
515⁄16
61⁄4
65⁄8
615⁄16
71⁄4
75⁄8
713⁄16
81⁄4
85⁄8
815⁄16
91⁄4
99⁄16
97⁄8
101⁄4
107⁄16
107⁄8

13⁄8
11⁄2
13⁄4
21⁄16
21⁄2
25⁄8
3
31⁄4
39⁄16
313⁄16
37⁄8
41⁄4
45⁄8
411⁄16
51⁄4
53⁄8
53⁄4
515⁄16
65⁄16
61⁄2
65⁄8
71⁄16
75⁄16
711⁄16
8
83⁄16
89⁄16
87⁄8

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1
1
1 ⁄16
11⁄8
11⁄8
11⁄8
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11⁄4
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13⁄8
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11⁄2
117⁄32
19⁄16
15⁄8
111⁄16
13⁄4
17⁄8
115⁄16
2
21⁄16
21⁄8
23⁄16
21⁄4
25⁄16
23⁄8
27⁄16

13 16

3 16

78

7 32

⁄
⁄
5⁄16
11⁄32
3⁄8
13⁄32
7⁄16
15⁄32
1⁄2
17⁄32
9⁄16
19⁄32
5⁄8
21⁄32
11⁄16
23⁄32
3⁄4
25⁄32
13⁄16
27⁄32
7⁄8
29⁄32
15⁄16
31⁄32
1
11⁄32
14

9 32

34
78

TABLE 2 Dimensions in Millimetres of Types III and IV Wildcats for Chains
Size of
Chain
⁄
⁄

34
78

1
11⁄8
11⁄4
13⁄8
11⁄2
15⁄8
13⁄4
17⁄8
2
21⁄8
21⁄4
23⁄8
21⁄2
25⁄8
23⁄4
27⁄8
3
31⁄8
31⁄4
33⁄8
31⁄2
35⁄8
33⁄4
37⁄8
4
41⁄8

R

R1

R2

R3

X

A

B

O

P

S

T

U

V

R4

R5

End Play
of Link

104.6
121.9
138.4
157.0
174.5
192.0
209.3
226.8
244.6
261.9
279.1
296.7
314.2
331.5
349.0
366.5
383.8
401.3
418.6
436.1
453.4
471.2
488.4
506.0
523.2
541.0
558.3
575.8

103.9
121.2
137.9
155.4
173.0
190.5
207.8
225.3
243.1
260.4
277.6
295.1
312.7
329.9
347.5
365.0
382.5
399.8
417.1
434.6
451.9
469.6
486.9
504.4
521.7
539.5
556.8
574.3

76.2
88.9
101.6
117.3
130.0
142.7
157.2
171.5
185.7
199.9
212.6
225.3
241.3
254.0
269.8
285.8
298.5
311.2
323.9
336.6
352.3
365.0
381.0
393.7
406.4
422.1
431.8
444.5

123.7
144.3
164.8
185.7
206.2
226.8
247.4
268.0
288.8
309.4
329.9
350.5
371.3
391.7
412.5
433.1
453.6
474.2
494.8
515.6
535.9
556.8
577.3
597.9
618.5
639.3
659.9
680.5

60.3
68.3
76.2
82.6
88.9
95.3
103.2
111.1
119.1
127.0
133.4
141.3
149.2
157.2
165.1
173.0
181.0
188.9
196.9
204.8
212.7
220.7
228.6
236.5
238.1
252.4
260.4
268.3

34.9
38.1
41.3
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50.8
54.0
57.2
63.5
69.9
73.0
76.2
79.4
85.7
88.9
92.1
98.4
101.6
108.0
111.1
117.5
120.7
127.0
130.2
136.5
142.9
146.1
152.4
158.8

85.7
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174.6
187.3
200.0
212.7
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235.0
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273.1
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374.7
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400.1
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60.3

33.3
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46.8
53.2
57.9
64.3
73.0
77.0
82.6
87.3
91.3
99.2
104.8
112.7
116.7
124.6
128.6
133.4
140.5
145.3
153.2
157.2
167.5
171.5
177.0
182.6
193.7

37.3
41.3
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69.1
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113.5
120.7
128.6
136.5
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157.2
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172.2
178.6
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192.1
202.4
206.4
214.3
223.9
230.2

67.5
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100.8
112.7
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158.8
170.7
181.0
193.7
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227.0
238.1
252.4
261.9
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284.2
288.9
306.4
315.9
330.2
341.3
352.4
363.5
376.2

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23.0
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26.2

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117.5
125.4
133.4
142.9
150.8
158.8
168.3
176.2
184.2
193.7
198.4
209.6
219.1
227.0
235.0
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108.0
117.5
119.1
133.4
136.5
146.1
150.8
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165.1
168.3
179.4
185.7
195.3
203.2
208.0
214.3
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47.6
49.2
50.8
52.4
54.0
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57.2
58.7
60.3
61.9

3


FIG. 2 Wildcat Development
R₃ = mean effective radius, measured to the outside center of a link laying in the displaced position in a pocket,  

\[ R₃ = \sqrt{\frac{g}{0.309 \ 02} + \frac{d}{0.951 \ 06}} \]  

R₄ = L − 3.36d.

8. Workmanship, Finish, and Appearance

8.1 Castings shall be smooth, of fine grain, and free of cracks, hot tears, and blow holes, detrimental to end use.

8.2 Castings shall have all flash material, vents, and gates removed and ground flush to match the surrounding surface.

8.3 Welds shall be extended around the ends of members and be free of pockets and irregularities that would tend to trap water or mud.

8.4 Castings and weldments shall be sand- or shot-blasted to remove all loose scale and slag.

8.5 The outside faces of the wildcat flanges shall be machined to the extent necessary to rotate in true planes.

9. Test Method

9.1 To test the fit of the sample chain on the wildcat, use a nine-link sample consisting of five joined common links, one detachable link, and three joined common links. The sample chain shall be uniform, representative of the chain to be used, and conform to American Bureau of Shipping Grade 1, 2, or 3.

9.2 Wrap the sample chain tightly around the wildcat, starting with the first common link in a pocket (see Fig. 1). The link grip dimension of the closure (gap) shall not exceed the link grip length or be less than the link grip length minus 3/8 times the chain size.

9.3 The dimensions of the wildcat may be reduced by chipping, grinding, or air-arc cutting for an acceptable chain fit. If air-arc cutting is used, not less than the last 1/8 in. (3 mm) of material shall be removed to a smooth contour by grinding. Do not use flame cutting.

9.4 By consent of the purchaser, weld cladding or hard surfacing may be used to build up chain contact surfaces for an acceptable chain fit. The Brinell hardness of the finished weld deposit shall be the same as the adjacent area of the base material, plus or minus 25-HB hardness points for Types I and III, and plus or minus 50-HB hardness points for Types II and IV. Hardness measurements shall be made in accordance with requirements of Test Method E 10.

10. Inspection

10.1 The wildcat shall be visually inspected for workmanship, finish, and appearance, after cleaning by sand- or shot-blasting.

11. Marking (Shipping)

11.1 Each wildcat, when furnished as a separate component, shall be marked with the ASTM designation, purchase order, and item number. Marking shall be by point or weatherproof tag.

12. Packaging

12.1 Wildcats, when furnished as a separate component, shall be crated, skidded, or attached to a pallet in a manner acceptable for handling by a common carrier. When wildcats are furnished with machined bore and hub, machined surfaces shall be protected against corrosion in open weather storage for periods of at least one year.

13. Keywords

13.1 anchor chain; stud link anchor chain; wildcats; windlasses
Standard Specification for Doors, Furniture, Marine

This standard is issued under the fixed designation F 782; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope
1.1 This specification covers the construction of furniture doors for use where invoked by other marine furniture specifications.
1.2 This specification applies to all furniture doors for marine furniture, in items requiring hinged doors.
1.3 Values stated in inch-pound units are to be regarded as the standard. The metric equivalents, given in parentheses, are for information only.

2. Referenced Documents
2.1 ASTM Standards:
A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 1008/A 1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
C 1036 Specification for Flat Glass
D 907 Terminology of Adhesives
2.2 American Institute of Steel Construction Manual:
AISC Wire and Sheet Metal Gages—Equivalent Thickness in Decimals of an Inch, U.S. Standard Gage (USSG) for Uncoated Hot and Cold-Rolled Sheets

3. Terminology
3.1 Definitions of Terms Specific to This Standard:
3.1.1 flush doors—metal doors with a smooth surface on the exterior face.
3.1.2 hinged door—door equipped with hinges that permit it to swing about the vertical hinge axis, either right hand or left hand.
3.1.2.1 right-hand door—door with hinges on the right side when viewed from the exterior of the furniture item containing the door.
3.1.2.2 left-hand door—door with hinges on the left side when viewed from the exterior of the furniture item containing the door.
3.1.3 panel doors—doors with metal stiles and rails that support a panel insert of transparent safety glazing or expanded aluminum.
3.1.3.1 stiles—the vertical members in the frame of a panel door that support the central panel.
3.1.3.2 rails—the horizontal members in the frame of a panel door that support the central panel.

2.3 Federal Specifications:
DD-G-1403 Glass, Plate (Float), Sheet Figured, and Sndrel (Heat Strengthened and Fully Tempered)
LP-391 Plastic Sheets, Rods and Tubing, Rigid Cast, Meth-acrylate (Multiapplication)
QQ-C-320 Chromium Plating (Electrodeposited)
QQ-Z-325 Zinc Coating, Electrodeposited
2.4 American National Standard Institute Standards:

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.
2 Annual Book of ASTM Standards, Vol 01.03.
3 Annual Book of ASTM Standards, Vol 01.05.
4 Annual Book of ASTM Standards, Vol 02.02.
5 Annual Book of ASTM Standards, Vol 01.05.
6 Available from the American Institute of Steel Construction, 400 N. Michigan Ave., Chicago, IL 60611.
7 Available from the American National Standards Institute, 25W. 43rd St., 4th Floor, New York, NY 10036.
8 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
9 Available from American National Standards Institute, 25W. 43rd St., 4th Floor, New York, NY 10036.
4. Classification

4.1 Doors shall be of the following types as required by the specifications for the item of furniture in which they are installed and as indicated in ordering documents. See Fig. 1 for details.

4.1.1 *Type I*—Flush hinged door.
4.1.2 *Type II*—Panel hinged door.

5. Ordering Information

5.1 Doors are included as part of the orders for items of furniture requiring doors. To describe adequately the door or doors required, these orders shall include, as necessary, the following information:

5.1.1 Type.
5.1.2 Size, see Section 8.
5.1.3 Paint:
5.1.3.1 *Color*—Per the purchaser’s requirements.

5.1.3.2 Manufacturer’s standard baked enamel will be furnished unless otherwise required and indicated by the purchaser.

5.1.4 For single-hinged doors, indicate hand if not obvious or if a specific hand is required.

5.1.5 Material for Type II (panel) doors may be either steel or aluminum. Material selected shall be the option of the furniture purchaser.

6. Materials and Manufacture

6.1 For typical design, see Fig. 1.

6.2 Sheet metal shall be cold-rolled steel, commercial quality, furniture grade in accordance with Specification A 1008/A 1008M.

6.3 Aluminum extrusions shall be Type 6063-T6 aluminum alloy in accordance with Specification B 221. Aluminum sheet shall be Type 5052-H32 aluminum alloy in accordance with Specification B 209.

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**TABLE 1 Table of Dimensions**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
</tr>
<tr>
<td>Door thickness A</td>
<td>1 max</td>
</tr>
<tr>
<td>Width of stile or height of rail B</td>
<td>3 max</td>
</tr>
</tbody>
</table>

**NOTE 1**—Panels of Type I (flush) doors shall be cold-rolled sheet steel, commercial quality, furniture grade in accordance with Specification 366/A 1008/A 1008M, 18 USSG (0.0478 in. or 1.21 mm). Stiffeners shall be applied to front and back as required to prevent buckling or oil-canning.

**NOTE 2**—At the option of the furniture manufacturer the stiles and rails for Type II (panel) door, may be either 18 USSG (0.0478 in. or 1.21 mm) cold-rolled steel, commercial quality, furniture grade in accordance with Specification A 1008/A 1008M or Type 6063-T6 extruded aluminum in accordance with Specification B 221 or 0.064-in. (1.63-mm) thick Type 5052-H32 aluminum alloy sheet in accordance with Specification B 209.

**NOTE 3**—Aluminum Panel inserts for Type II (panel) doors shall be Type 3003-H14 anodized aluminum, 0.081 in. (2.06 mm) thick before expanding and of the Festoon or other approved pattern. Material shall be in accordance with Specification B 209 and the anodizing shall be done after metal is expanded. Alternative safety glazing can be furnished if specified in ordering documents. See 6.11.2.1 for description of these alternatives.

**NOTE 4**—Butt hinges are shown in Fig. 1 and shall be furnished in accordance with 6.8. Type 300 stainless steel pivot or hinges of adequate strength may be used in place of butt hinges.

**NOTE 5**—Stay arms shall be provided and shall both prevent door from opening more than 90° and be capable of retaining door in 90° open position.

**NOTE 6**—Doors shall be equipped with latches. See 6.7.1 and 6.7.2 for description of alternative latches.

**NOTE 7**—Doors shall be capable of resisting vertical load applied at latch edge. See 7.1 for detail of test.

**NOTE 8**—Doors shall be comply with requirements of tilt test. See 7.2 for details of test.

**FIG. 1** Furniture Doors
6.4 Joining of metal parts:

6.4.1 Metal components shall be joined by welding or gluing with a structural adhesive as defined in Terminology D 907.

6.4.2 Joining shall be adequate to prevent racking during handling.

6.4.3 Spotwelds shall be spaced approximately 3 in. (76.2 mm) on centers.

6.4.4 Visible spotwelds on exterior face of door higher than the general surface of the metal shall be ground flush.

6.4.5 Visible spotweld depressions shall be spot filled and sanded flush.

6.5 All doors shall be square and form a plane through the four corners.

6.6 All doors shall incorporate a latch or other positive means to prevent opening in heavy seas. Spring, bullet, magnetic, or bayonet-type catches shall not be permitted. Furniture doors shall not open when furniture unit in which door is installed is tilted a maximum of 30° from the vertical.

6.7 Latches for doors shall be one of the two following types as selected by the furniture purchaser:

6.7.1 Mortise type of brass, bronze, or stainless steel, attached with stainless steel fasteners. Exposed brass or yellow bronze parts shall be Class I, Type II chrome plated in accordance with Federal Specification QQ-C-320. Exposed stainless steel and white bronze parts shall have a brushed finish. White bronze shall be covered with a clear protective coating of lacquer or other similar covering.

6.7.2 Two point latching rod system with hardware similar to that in use for marine type furniture doors. Disk tumbler cam locks may be used to prevent rods from unlatching. Omit dummy hardware on inactive door for double door applications. Disk tumbler cam locks shall have 90° rotation with screwed on or spun-on cap attachment. Cylinders shall be die-cast zinc with exposed surfaces finished in satin nickel-plated US-15 finish.

6.8 Hinges shall be provided and shall be Type 300 stainless steel in accordance with Specification A 240 with a Type 300 stainless steel pin in accordance with Specification A 582. Hinges shall be of adequate size Please find the attached proof copy of F 2119. Please make sure that it has been edited correctly. I will bring any questions/concerns that you have to the F 04 editor, Kathy Peters. Please respond on or before September 14, 2001. After this date, F 2119 will be published as a separate. Thank you for your time. with 1⁄16-in. (1.59-mm) thick leaves and secured with Type 300 stainless steel or zinc-plated steel fasteners. Zinc-plated fasteners shall be in accordance with QQ-Z-325 Cl 2, Ty 1. Type 300 stainless steel pivot or piano hinges of adequate strength may be used in place of butt hinges.

6.9 Stay arms shall be provided and shall prevent door from opening more than 90° and be capable of retaining door in 90° open position.

6.10 Type I (flush) doors shall have additional requirements as follows:

6.10.1 Front and/or back panels shall be cold-rolled sheet steel, commercial quality, furniture grade in accordance with Specification A 1008/A 1008M, 18 USSG (0.0478 in. or 1.21 mm).

6.10.2 Stiffener shall be applied to front and/or back panels as required to prevent buckling or oil-canning.

6.11 Type II (panel) doors shall have the additional requirements as follows:

6.11.1 At the option of the furniture manufacturer, the stiles and rails may be either 18 U.S.S.G (0.0478-in. 1.21-mm) cold-rolled steel, commercial quality, furniture grade in accordance with Specification A 1008/A 1008M, Type 6063-T6 extruded aluminum alloy in accordance with Specification B 221, or 0.064-in. (1.63-mm) thick Type 5052-H32 aluminum alloy sheet in accordance with Specification B 209.

6.11.2 Panel Inserts—Unless otherwise specified in ordering documents, panel inserts shall be expanded aluminum in accordance with 6.11.2.2.

6.11.2.1 Panel inserts of transparent safety glazing shall be either 3/16-in. (4.76 mm) thick safety glass, of the heat-treated or laminated type, or 3⁄16-in. (4.76-mm) thick acrylic sheet. Material specifications for these transparent panel inserts are as follows: heat-treated safety glass in accordance with Specification C 1036 and Federal Specification DD-G-1403; laminated safety glass in accordance with Specification C 1036; acrylic sheet in accordance with Federal Specification LP-391. In addition, all transparent safety glazing shall meet the pertinent safety requirements of ANSI Specification Z97.1-1975.

6.11.2.2 Expanded aluminum panel inserts shall be Type 3003-H14 anodized aluminum, 0.081 in. (2.06 mm) thick before expanding, and of the Festoon or other approved pattern. Material shall be in accordance with Specification B 209 and the anodizing shall be done after metal is expanded.

6.11.3 Provision for supporting and replacing the panel inserts shall be made.

7. Performance Requirements

7.1 Doors shall be capable of supporting a vertical load of 100 lb (45.4 kg), applied at the lock edge of door, with door in any position from 10° open to 90° open. Load shall remain on door for a minimum of 3 min and there shall be no indication of permanent set after removal of load.

7.2 Tilt Test—Doors shall remain latched in closed position when the furniture unit in which they are installed is tilted 30° from the vertical in the plane that would induce the greatest tendency for door to open. Leave door in this attitude for a minimum of three minutes.

8. Dimensions

8.1 For dimensions, see Table of Dimensions under Fig. 1.

8.2 Doors shall be made to a size that suits the furniture item in which they are installed.

9. Workmanship, Finish, and Quality Assurance

9.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice to produce each item for its intended use.
9.2 All exposed burrs, raw, or sharp edges that might be injurious to personnel shall be removed.
9.3 Depressions considered unacceptable for product’s end use shall be spot filled and sanded smooth.
9.4 Finish:
9.4.1 All steel surfaces, unless corrosion-resistant or with a corrosion-resistant plating, shall be painted so as to prevent corrosion.
9.4.2 Unless otherwise required by the furniture specification, all normally visible parts of completed unit shall have the manufacturer’s standard baked-on enamel finish.
9.4.3 Color—Doors shall be painted per the purchaser’s color requirements.

10. Inspection and Certification
10.1 Inspection and certification requirements of furniture item in which door (or doors) are installed shall govern.

11. Packaging and Package Marking
11.1 Each door shall be installed in its respective furniture item prior to shipment. Marking and packaging requirements of furniture item shall govern.

12. Keywords
12.1 doors; flush hinged door; furniture; furniture doors; hinged doors; marine; marine furniture; panel hinged door; ship
Standard Specification for
Staple, Handgrab, Handle, and Stirrup Rung

1. Scope
1.1 This specification provides design, construction for steel staples, handgrabs, handles, and individual stirrup rungs.
1.2 The staples, handgrabs, and handles depicted in this specification are for use on steel structures including all parts of ships’ structure as necessary. The individual stirrup rungs are for use on bulkheads or structure as deemed necessary.
1.3 Values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents
2.1 ASTM Standards: 2
   A 575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades

3. Terminology
3.1 Definitions of Terms Specific to This Standard:
3.1.1 handgrab or handle—bent round bar of various sizes for use on miscellaneous hatch covers, manholes, above access openings, and so forth.
3.1.2 staple—a U-shaped round bar of various sizes used to provide an anchor end for lashings, portable chain connections, lifting slings, and so forth.
3.1.3 stirrup rung—a double-bend-shaped square bar intended for use as a single step or supplementary steps in place of a vertical ladder.

4. Ordering Data
4.1 The purchaser’s ordering data shall include the following:
4.1.1 Quantity, size, and type.
4.1.2 Finish if other than specified in 7.1 and 7.2.

5. Materials and Manufacture
5.1 Staple, handgrab, handle, and stirrup rung shall be made of steel in accordance with Grade M 1020 of Specification A 575.

6. Dimensions
6.1 Dimensions of staple shall be as indicated in Table 1.
6.2 Dimensions of handgrab and handle shall be as indicated in Table 2.
6.3 Dimension of stirrup rung shall be as indicated in Table 3.
6.4 Dimensions are given in inches; millimetre equivalents appear in parentheses, and apply to this specification only.

7. Finish
7.1 Unless otherwise required by the ordering data, manufacturer’s standard sandblast shall be acceptable. All rough edges shall be dressed smooth by grinding.
7.2 Unless otherwise required by the ordering data, all staples, handgrabs, handles, and stirrup rungs shall be coated with a nonhazardous corrosion inhibiting primer coating by the manufacturer.

8. Product Marking
8.1 Each staple, handgrab, handle, and stirrup rung shall be marked with the purchase order number, item number from purchase order, ASTM designation number, and manufacturer’s name. Marking may be by paint, stencil, or weatherproof tag.

9. Packaging and Package Marking
9.1 Packaging shall be provided and be acceptable to a common carrier.

10. Keywords
10.1 bulkheads; handgrabs; handles; marine steel structures; stirrup rung

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting and Deck Machinery.

2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.
TABLE 1  Dimensions of Staple, in. (mm)

<table>
<thead>
<tr>
<th>Type</th>
<th>Round Bar Diameter, in. (mm)</th>
<th>Dimensions, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>¾ (10)</td>
<td>¾ (10) 1 (25)</td>
</tr>
<tr>
<td>II</td>
<td>1½ (13)</td>
<td>¾ (16) 1½ (38)</td>
</tr>
<tr>
<td>III</td>
<td>5/8 (19)</td>
<td>1½ (38) 2 (51)</td>
</tr>
<tr>
<td>IV</td>
<td>1 (25)</td>
<td>1½ (44) 3 (76)</td>
</tr>
<tr>
<td>V</td>
<td>1½ (38)</td>
<td>2 (51) 4 (102)</td>
</tr>
</tbody>
</table>

TABLE 2  Dimensions of Handgrasp and Handle, in. (mm)

<table>
<thead>
<tr>
<th>Type</th>
<th>Round Bar Diameter in., (mm)</th>
<th>Dimensions, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>½ (13)</td>
<td>5 (127) 2½ (64) ½ (13)</td>
</tr>
<tr>
<td>II</td>
<td>5/8 (16)</td>
<td>12 (305) 4 (102) 15/16 (24)</td>
</tr>
<tr>
<td>III</td>
<td>5/8 (16)</td>
<td>8 (203) 4 (102) 15/16 (24)</td>
</tr>
</tbody>
</table>
### TABLE 3 Dimensions of Stirrup Rung, in. (mm)

<table>
<thead>
<tr>
<th>Type</th>
<th>Square Bar</th>
<th>Dimensions, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>I</td>
<td>3/4 (19)</td>
<td>16 1/4 (425)</td>
</tr>
</tbody>
</table>

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1. Scope

1.1 This specification covers the construction of standard and custom-built interior steel doors and frames for ships including U.S. Coast Guard certificated vessels with domestic routes.

1.2 Doors and frames are to be hollow metal construction with the door insulated for sound or fire.

1.3 The doors are intended for use in staterooms, lavatories, passageways, and other areas protected from weather.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

2. Referenced Documents

2.1 ASTM Standards:
A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
A 1008/A 1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability
E 136 Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C

2.2 Code of Federal Regulations (CFR) Title 46—Shipping:
Subchapter D—Tank Vessels, Subpart 32.57—Structural Fire Protection
Subchapter H—Passenger Vessels, Subpart 72.05—Structural Fire Protection
Subchapter I—Cargo and Miscellaneous Vessels, Subpart 92.07—Structural Fire Protection
Subchapter T—Small Passenger Vessels, Subpart 177.300—Hull Structure
Subchapter U—Oceanographic Vessels, Subpart 190.07—Structural Fire Protection
Structural Insulations, Subpart 164.007
Noncombustible Materials for Merchant Vessels, Subpart 164.009
Noncombustible Materials, Subpart 164.109

2.3 Builders Hardware Manufacturers Association, Inc.: A 156.18 Materials and Finishes

2.4 U.S. Public Health Service: Publication No. 393, Handbook on Sanitation of Vessel Construction

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 hands of doors—a term used to describe a door from the outside or key side of the door.
3.1.2 right-hand regular door—a door having hinges on the right side when swinging door away from the individual opening it.
3.1.3 left-hand regular door—a door having hinges on the left side when swinging door away from the individual opening it.
3.1.4 right-hand reverse bevel door—a door having hinges on right side when swinging door towards the individual opening it.
3.1.5 left-hand reverse bevel door—a door having hinges on left side when swinging door towards the individual opening it.
3.1.6 face plates—the exterior metal skins that enclose the internal supporting structure of the door.
3.1.7 latch—a device normally installed in the vertical edge of door, opposite hinge edge, that when latched retains door in closed position.

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.


2 Annual Book of ASTM Standards, Vol 01.03.
3 Annual Book of ASTM Standards, Vol 01.05.

7 Available from United States Public Health Services, Division of Engineering Services, Parklawn Library, Room 1315, 5600 Fishers Lane, Rockville, MD 20857, Attention: Ms. Bonnie Scott.
3.1.8 *throw*—the extension, or reach, of the latch bolt. This throw is measured from latch face plate to extreme outer edge of latch bolt with latch bolt in fully extended position.

3.1.9 *padlock eye*—a means for securing door in closed position by the use of a padlock.

4. **Classification**

4.1 Classes of doors and frames shall be as indicated in the ordering information. (See Annex A1 for definition of various class divisions.)

4.1.1 Class A-O for installation in Class A-O divisions.

4.1.2 Class A for installation in Class A-15, A-30, and A-60 divisions.

4.1.3 Class B for installation in Class B divisions.

4.1.4 Class C for installation in Class C divisions.

4.2 Doors and frames shall be of the following types as indicated in ordering information.

4.2.1 Type I standard doors are of the following widths. Height and details shall conform to Tables 1-6 and Figs. 1-3.

Size 1—22-in. (559-mm) clear jamb width

Size 2—24-in. (610-mm) clear jamb width

Size 3—26-in. (660-mm) clear jamb width

Size 4—30-in. (762-mm) clear jamb width

Size 5—36-in. (914-mm) clear jamb width

4.2.2 Type II doors conforming generally to specifications but requiring special requirements as indicated in the ordering information (see also 6.7.9).

4.2.3 Type III double doors using two of Type I doors.

4.2.4 Type IV double doors using two of Type II doors.

**NOTE 1**—Door widths are approximately 1 1/4 in. (approximately 32 mm) greater than clear jamb width.

5. **Ordering Information**

5.1 Orders for items under this specification shall include the following information by the purchaser:

5.1.1 Class A-O, A, B, or C.

5.1.2 Type, hand, clear jamb width, and sill height.

5.1.3 Options such as vent grills, louvers, vision lights, and hose ports.

5.1.4 Hardware, sill caps, lock sets, latches, door closers, and hold backs if other than manufacturer’s standard. Master keying of door locks will not be provided unless required and defined by ordering documents. Instead, each door lock will be keyed differently.

5.1.5 Color chip and desired painting specifications or other commercial designation for final finish. If not specified, doors will have manufacturer’s prime coat applied.

**TABLE 1** Class A-O and Class A Door Dimension

| Designation                              | A     | 1 1/4 | 45  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear height from structural deck</td>
<td>B</td>
<td>78%</td>
<td>1994</td>
</tr>
<tr>
<td>Clear height from finished deck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height from structural deck to center line of vision light</td>
<td>C</td>
<td>approximately 78</td>
<td>approximately 1981</td>
</tr>
<tr>
<td>Height from structural deck to center line of cutout for switch</td>
<td>D</td>
<td>64</td>
<td>1626</td>
</tr>
<tr>
<td>Height from structural deck to center line of knob</td>
<td>E</td>
<td>48</td>
<td>1219</td>
</tr>
<tr>
<td>Undercut</td>
<td>F</td>
<td>38</td>
<td>965</td>
</tr>
<tr>
<td>Sill height</td>
<td>G</td>
<td>see Table 2</td>
<td>see Table 2</td>
</tr>
</tbody>
</table>

5.1.6 For Type II and III doors, sizes and any other supplementary requirements.

5.1.7 *Sill Heights*—0 in. (0 mm), 1½ in. (38 mm), or 6 in. (152 mm). See Figs. 1-3.

5.1.8 Cut out for light switch; if not requested in ordering data, no provisions will be made.

6. **Materials and Manufacture**

6.1 For typical design, see Figs. 1-3.

6.2 Steel for doors and frames shall be cold-rolled sheet, commercial quality in accordance with Specification A 1008/A 1008M. Other materials shall be as indicated.

6.3 Class A-O Doors (See Fig. 1 and Table 1 and Table 2):

6.3.1 Door shall be 1¼-in. (45-mm) thick hollow steel with 0.055-in. (1.4-mm) minimum face plates or equivalent metal construction.

6.3.2 Doors shall have a latch with a minimum throw of ¾ in. (19 mm).

6.3.3 Door frames shall be of steel with a nominal thickness of 0.055 in. (1.4 mm) and shall be installed so that any flame penetration would be through at least two thicknesses of 0.055 in. (1.4 mm) or equivalent.

6.3.4 Door frames shall provide a stop of 1/8 in. (16 mm) minimum at the sides and top.

6.3.5 For undercut at bottom of door, see Fig. 1 and Table 2.

6.3.6 Doors other than those that are normally locked shall be self closing and capable of closing against a 3½° list.

6.3.7 Doors shall be insulated with sufficient noncombustible fibrous insulation to sound dampen the door adequately. This insulation shall be selected from those listed under Section 164.007, Structural Insulations, or Section 164.009, Noncombustible Materials.

6.3.8 *Options for Class A-O and A Doors*:

6.3.8.1 Vision lights may be installed using wire-inserted glass of not more than 100 in.² (645 cm²) in size.

6.3.8.2 An escape panel of 16- by 18-in. (406- by 457-mm) minimum size in lower half of door.

6.3.9 Note: Undercut at bottom of door, see Fig. 1 and Table 2.
6.3.8.3 Where hose ports are required, they shall be cut in the lower corner of the door on the side opposite the hinges so that when hose is passed through the door when the door is open, it may be closed over the hose. The cut for the host port should be approximately 8 by 8 in. (200 by 200 mm). A hinged or pivoted steel metal cover shall be fitted in the cut, equipped with a method of holding it in a closed position yet will permit easy and automatic operation of the hinged cover. See Fig. 1 for location.

6.4 **Class A Doors** (see Fig. 1 and Table 1 and Table 2):

6.4.1 Doors and frames shall follow the requirements of 6.3.1-6.3.6 and 6.3.8.

6.4.2 Doors shall be filled solidly with one half the thickness of structural insulation with USCG Approval Number 164.007. Insulation with USCG Approval Number 164.107 (A-15 rating) may also be used.

6.5 **Class B doors** (see Fig. 2 and Table 3 and Table 4):

6.5.1 Doors shall be 1¾-in. (45-mm) thick hollow steel and constructed of a minimum of 0.044-in. (1.1-mm) face plates.

6.5.2 Doors shall have a latch with a minimum throw of ½ in. (13 mm).

6.5.3 Door frames shall be steel with a minimum 0.055-in. (1.4-mm) thickness if they are an open channel design and a minimum 0.044 in. (1.1 mm) if they are a tubular design. Aluminum construction is acceptable and other noncombustible materials will also be considered.

6.5.4 Door frames shall provide a stop of 5/8 in. (16 mm) minimum at the sides and top.

6.5.5 For undercut at bottom of door, see Fig. 2 and Table 4.

6.5.6 Doors shall be insulated with sufficient noncombustible insulation to sound damp the door adequately. This insulation shall be selected from one of the following USCG approval categories: 164.007, 164.009, 164.107, or 164.109.

6.5.7 **Options for Class B Doors**:

6.5.7.1 Doors may be fitted with any amount of wire inserted glass, as door construction permits.

6.5.7.2 The lower half of such doors may have a louver. The total net area of louver plus any door undercut shall not exceed 78 in.² (0.05 m²).

6.5.7.3 An escape panel of 16- by 18-in. (406- by 457-mm) minimum size.

6.6 **Class C Doors** (see Fig. 3 and Table 5 and Table 6):

6.6.1 Doors shall be 1¾-in. (45-mm) thick hollow steel and constructed of 0.044-in. (1.1-mm) face plates. Aluminum construction is acceptable and other noncombustible materials will also be considered.

6.6.2 Doors shall have a latch with a minimum throw of ½ in. (13 mm).

6.6.3 Door frames shall be steel with a minimum 0.055 in. (1.4 mm) if they are an open channel design and a minimum 0.044 in. (1.1 mm) if they are a tubular design. Aluminum construction is acceptable and other noncombustible materials will also be considered.

6.6.4 Door frames shall provide a stop of ⅜ in. (16 mm) minimum at the sides and top.

6.6.5 For undercut at bottom of door, see Fig. 3 and Table 6.

6.6.6 Doors shall be insulated with sufficient noncombustible fibrous insulation to sound damp the door adequately. This insulation shall be selected from those listed in the Section 164.007, Structural Insulations, or Section 164.009, Noncombustible Materials.

6.6.7 **Options for Class C Doors**:

6.6.7.1 Doors may be fitted with any amount of clear safety glass (laminated or heat treated) as door construction permits.

6.6.7.2 There are no restrictions on louver size, except that dictated by door size and construction.

6.6.7.3 Padlock eyes for crew wardrobes may be furnished if specified in ordering information, see Fig. 3 for location.

6.7 **Other Requirements for All Doors**:

6.7.1 Doors and frames shall be made square and parallel to vessel baseline, without sheer or camber.

6.7.2 Sills or sill caps shall be Series 300 stainless steel in accordance with Specification A 240/A 240M with a mill finish.

6.7.3 Where glass is required in doors, it shall be at least ¼ in. (6 mm) thick.

6.7.4 Double doors capable of independent operation and latching shall have a clearance between doors not to exceed ⅛ in. (3 mm). Double doors incapable of independent operation shall have a ½-in. (13-mm) stop or astragal between doors.

6.7.5 Doors that require door closers shall be reinforced in way of attachments to door and frame. Doors that require hold open hooks and bumpers shall be reinforced in way of attachment to the door.

---

**TABLE 4 Class B Sill Details**

<table>
<thead>
<tr>
<th>Sill Height (G)</th>
<th>Maximum Door Undercut (F)⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation</td>
<td>in.</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1.5</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>6⁵</td>
</tr>
<tr>
<td>F</td>
<td>6⁵</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Designation</th>
<th>in.</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>See Table 4</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>See Table 4</td>
<td></td>
</tr>
</tbody>
</table>

---

⁴In passageways and areas in which ratproofing requirements are invoked, the height of the door undercut shall not exceed ½ in. (13 mm).

⁵Max coaming height under sill is 5 in. (127 mm).
6.7.6 Hinges shall be Series 300 stainless steel in accordance with Specification A 240/A 240M with a Series 300 stainless steel pin in accordance with Specification A 582/A 582M. Where fire performance requirements permit, brass or bronze hinges and fasteners may be used. The hinges shall be mortise type 4½ in. (114 mm) high with ⅛-in. (3-mm) thick leaves with Series 300 stainless steel fasteners.

6.7.6.1 All doors shall be equipped with three hinges, equally spaced. Suitable reinforcements shall be installed in doors and frames to support all hinges properly.

6.7.7 Locksets shall be heavy-duty design, key in knob type, with Series 300 stainless steel mechanism. Knob roses and other exposed parts may be brass or bronze, chrome plated per BHMA A 156.18, finish code number 626 or equivalent brushed finish Series 300 stainless steel.

6.7.8 Where construction of door and frame is of steel, it shall be of welded construction with spot welds spaced 6 in. (152 mm) on centers or equivalent arc welds.

6.7.9 Special Construction—The following special construction will be furnished only if specified in ordering information.

6.7.9.1 Dutch doors will be furnished with hinged shelf of Series 300 stainless steel in accordance with Specification A 240/A 240M fitted to bottom half of door. Unless specified otherwise in ordering documents, width of hinged shelf shall be 8 in. (200 mm). Bottom half shall be fitted with lock as for similar doors and with slide bolt between door halves. Padlock eyes or custom seal eyes shall be provided if specified.

6.7.9.2 Double-acting doors, doors equipped with hinges that permit doors to swing both ways, with double bevel latch bolt or dead lock with key on outside and thumb turns on inside.

6.7.9.3 Fume tight door with gasket installed in stop of door frame and around the entire perimeter of door.

6.7.9.4 Door with acoustically lined louver shall have a noise reduction factor equal to that of the joiner bulkhead in
which it is hung or 20 decibels, whichever is lowest. Door frames shall be equipped with gasket similar to that for a fume tight door.

6.7.10 Operating Requirements:

6.7.10.1 All doors shall be capable of operation from either side by one person. Doors shall swing easily and freely on their hinges. The latch set or lock set shall operate freely.

6.7.10.2 Wherever practicable, interior doors are to open into compartments served and not into passageways. In public spaces, stairway enclosures, corridor exits, and so forth, all doors shall open in the direction of escape where practicable.

6.7.10.3 If it is desirable to use decorative doors in addition to those required, they shall be constructed of material classified as noncombustible by CFR 46, Subpart 164.009 and 164.109. These decorative doors shall not interfere with the normal operation of the required doors, and shall open in the same direction if the required doors are in a main avenue of escape.

7. Dimensions

7.1 For dimensions, see Tables 1 and 6.

8. Workmanship and Quality Assurance

8.1 All workmanship and materials to be of specified quality in keeping with this specification and the best commercial marine practice so as to produce each item suitable for its intended use. Doors and frames shall be visually inspected for any defects.

9. Finish

9.1 All steel, unless corrosion resistant or with corrosion-resistant plating, shall be cleaned and a commercial prime coat applied unless otherwise required by the ordering data.

9.2 All exposed burrs and raw or sharp edges on doors and frames which might be injurious to personnel shall be removed.

10. Certification

10.1 The producer or manufacturer shall furnish to the purchaser a certification that the doors and frames were manufactured and inspected in accordance with this specification and have been found to meet the requirements.

11. Packaging

11.1 Packaging shall be provided and be acceptable to a common carrier.

12. Keywords

12.1 A Class doors; B Class doors; C Class doors; hollow metal construction; interior steel doors; marine doors; marine frames; ships; steel doors

ANNEX

(Mandatory Information)

A1. DEFINITIONS OF INTERIOR DIVISIONS—JOINERWORK

A1.1 Class A Construction—Bulkheads, decks, and related structure of steel or equivalent metal construction made intact with the main structure of the vessel. Class A construction shall be capable of preventing the passage of smoke and flame for 1 h. If of steel, the minimum thickness for Class A construction of 0.1196 in. or 3.0 mm. Doors and other penetrations must be constructed to the same requirement to provide this integrity. Class A-O division have no insulating requirements but by the addition of approved structural insulations, Class A divisions can prevent thermal conduction of heat to the unexposed side of the division for time periods of 60, 30, or 15 min as required for Classes A-60, A-30, and A-15, respectively.

A1.2 Approved Structural Insulation—Noncombustible insulation that has been subjected to an approved fire test (CFR 46 164.007) and, in the proper, approved thickness, prevents the average temperature rise on the unexposed side from rising more than 250°F (139°C) above ambient and also prevents the temperature of one point from rising more than 325°F (180°C) above ambient for a period of 1 h.

A1.3 Class B Construction—Noncombustible bulkheads that are capable of preventing the passage of flame for 30 min.

A1.4 Class C Construction—Bulkheads or decks constructed of noncombustible materials.
A1.5 Noncombustible Material—Any material that has been subjected to an approved fire test (CFR 46 164.009 or Test Method E 136).

A1.5.1 Average Weight Loss—Not more than 50 %.

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Standard Specification for
Chest of Drawers (Chiffonier), Steel, Marine

This standard is issued under the fixed designation F 822; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the construction of marine chests of drawers (chiffoniers) of steel construction to be used in staterooms and other spaces.

1.2 Values stated in inch-pound units are to be regarded as the standard. The metric equivalents, given in parentheses, are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled
D 907 Terminology of Adhesives
F 825 Specification for Drawers, Furniture, Marine, Steel
F 826 Specification for Tops, Furniture, Marine, Steel
2.2 American Institute of Steel Construction Manual:
AISC Wire and Sheet Metal Gages— Equivalent Thickness in Decimals of an Inch, U.S. Standard Gauge for Uncoated Hot and Cold Rolled Sheets

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 chest of drawers (chiffonier)—a chest of drawers with four drawers. All four drawers may be of the same size.

4. Ordering Information

4.1 Orders for items purchased under this specification shall include the following information:
4.1.1 Quantity.
4.1.2 Paint:
4.1.2.1 Color—Purchaser shall pick from manufacturer’s samples or submit sample chip of color desired.

4.1.2.2 Manufacturer’s standard baked enamel will be furnished unless otherwise required and indicated by the purchaser.
4.1.3 Options for Tops:
4.1.3.1 Unless otherwise specified in the ordering documents, the top supplied by the furniture manufacturer may be, at his option, Type I, II, III, or IV in accordance with Specification F 826.
4.1.3.2 Color or pattern of top covering material shall be specified.
4.1.4 Options for Drawers:
4.1.4.1 Padlock eyes shall be furnished on each drawer when specified in ordering documents. This security device is normally used in crew living spaces.
4.1.4.2 Drawer locks shall be furnished when specified in ordering documents. Master keying of drawer locks will not be provided unless required and defined by the ordering documents. Instead, each drawer lock will be keyed differently. See Specification F 825 for lock description.
4.1.4.3 A security panel between the two middle drawers to provide two secure two-drawer storage areas for two crew members is only furnished when specified in ordering documents. All four drawers in this type chest will be of same size.
4.1.5 If the total weight of the chest of drawers is required, it shall be requested by the purchaser.

5. Materials and Manufacture

5.1 For typical design, see Fig. 1.
5.2 Sheet metal shall be in accordance with Specification A 366/A 366M, commercial quality.
5.2.1 Minimum sheet metal thicknesses shall be:
5.2.1.1 Sides and front rails 18 USSG (0.0478 in. or 1.2 mm).
5.2.1.2 Back 20 USSG (0.0359 in. or 0.9 mm).
5.2.1.3 Base frame 16 USSG (0.0598 in. or 1.5 mm).
5.3 Joining of Metal Components:
5.3.1 Metal components shall be joined by welding or gluing with a structural adhesive as defined in Terminology D 907. The back panel may be riveted to the case provided rivets are not visible after installation.
5.3.2 Joining shall be adequate to prevent racking of chest during handling.
5.3.3 Spotwelds shall be spaced approximately 3 in. (76 mm) on centers.

5.3.4 Visible spotwelds, higher than the general surface of the adjacent metal, shall be ground flush.

5.3.5 Visible spotweld depressions shall be spot filled and sanded flush.

5.4 Side panels shall be suitably stiffened to prevent buckling or oil-canning.

5.5 Sound deadening shall be vermin proof and applied to back and inner face of sides of chest. Location and thickness of applied sound deadener shall be as required to sound-deaden chest.

5.6 Top shall be manufactured in accordance with Specification F 826.

5.7 Drawers shall be manufactured in accordance with Specification F 825.

5.8 A furniture base shall be provided suitable for securing chest of drawers to deck.

6. Performance Requirements

6.1 The completed chest of drawers, with the top and drawers installed, shall satisfy the corresponding performance requirements outlined in Specifications F 825 and F 826.

7. Dimensions

7.1 For dimensions, see Table 1.

---

**TABLE 1 Chest of Drawers Dimensions**

<table>
<thead>
<tr>
<th>Designation</th>
<th>in.</th>
<th>Tolerance</th>
<th>Dimension</th>
<th>mm</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width A</td>
<td>36</td>
<td>1/16</td>
<td>914</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Height B</td>
<td>37</td>
<td>1/16</td>
<td>940</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Depth C</td>
<td>21</td>
<td>1/16</td>
<td>533</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Toe D</td>
<td>3</td>
<td>1/16</td>
<td>76</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Space, Front Toe E</td>
<td>4 max</td>
<td>1/16</td>
<td>102 max</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Space, Side Base Height F</td>
<td>4/16 max</td>
<td>1/16</td>
<td>121 max</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

---

*Note 1—For description of Type I, II, III, and IV tops, see Specification F 826.

Note 2—For description of drawers, see Specification F 825.

Note 3—For optional security panel, see 4.1.4.3.

Note 4—If chest of drawers is located in a corner, Dimension “E” next to this adjacent wall shall be 0 in. (0 mm). In all other cases, the minimum value for Dimension “E” shall be 3/4 in. (19.05 mm).

Note 5—The minimum value for Dimension “F” shall be 4 in. (102 mm).

FIG. 1 Chest of Drawers

A furniture base shall be provided suitable for securing chest of drawers to deck.

8. Workmanship, Finish, and Quality Assurance

8.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice so as to produce each item suitable for its intended use.

8.2 All exposed burrs, raw or sharp edges which might be injurious to personnel shall be removed.

8.3 Depressions considered unacceptable for products end use shall be spot filled and sanded smooth.
8.4 Finish:
8.4.1 All steel surfaces, unless corrosion resistant or with a corrosion-resistant plating, shall be painted so as to prevent corrosion.
8.4.2 Unless otherwise required by the ordering documents, all parts normally visible on the completed unit shall have the manufacturer’s standard baked-on enamel finish.
8.4.3 Color is to be specified in the ordering documents.

9. Inspection and Certification
9.1 Manufacturer shall inspect and certify that the item of furniture complies with the furniture specification and the loading requirements as defined in Section 6.

10. Packaging and Package Marking
10.1 Each item shall be marked in accordance with the purchase order.
10.2 Packaging shall be provided and shall be acceptable to a common carrier.

11. Keywords
11.1 chest of drawers; chiffoniers; marine chest of drawers; marine furniture
Designation: F 823 – 93 (Reapproved 1999)

An American National Standard

Standard Specification for
Desk, Log, Marine, Steel, with Cabinet

This standard is issued under the fixed designation F 823; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the construction of marine log desks of steel construction with cabinets.

1.2 Values stated in inch-pound units are to be regarded as the standard. The metric equivalents, given in parentheses, are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled

D 907 Terminology of Adhesives

F 782 Specification for Doors, Furniture, Marine

F 825 Specification for Drawers, Furniture, Marine, Steel

F 826 Specification for Tops, Furniture, Marine, Steel

2.2 American Institute of Steel Construction Manual:

AISC Wire and Sheet Metal Gages— Equivalent Thickness in Decimals of an Inch, U.S. Standard Gage for Uncoated Hot and Cold Rolled Sheets

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 log desk with cabinet—a desk with attached cabinet located in various places aboard ship for making records and for storage. Log desk has a drawer with a writing surface at the top and a cabinet with adjustable shelves and doors below.

4. Ordering Information

4.1 Orders for items purchased under this specification shall include the following information:

4.1.1 Quantity.

4.1.2 Paint:

4.1.2.1 Color—Purchaser shall pick from manufacturer’s samples or submit sample chip of color desired.

4.1.2.2 Manufacturer’s standard baked enamel will be furnished unless otherwise required and indicated by the purchaser.

4.1.3 Options for Tops:

4.1.3.1 Unless otherwise specified in the ordering documents, the top supplied by the furniture manufacturer may be, at his option, Type I, II, III, or IV in accordance with Specification F 826.

4.1.3.2 Color or pattern of top covering material shall be specified.

4.1.4 Options for Drawers—Drawer locks shall be furnished only when specified in ordering documents. Master keying of drawer locks will not be provided unless required and defined by the ordering documents. See Specification F 825 for lock description.

4.1.5 Options for Doors—Door locks shall be furnished only when specified in ordering documents. Master keying of door locks will not be provided unless required and defined in the ordering documents. Doors shall be Type I in accordance with Specification F 782.

4.1.6 If the total weight of the chest of drawers is required it shall be requested by the purchaser.

5. Materials and Manufacture

5.1 For typical design, see Fig. 1.

5.2 Sheet metal shall be in accordance with Specification A 366/A 366M, commercial quality.

5.2.1 Minimum sheet metal thickness shall be:

5.2.1.1 Sides and front rails 18 USSG (0.0478 in. or 1.2 mm).

5.2.1.2 Back 20 USSG (0.0359 in. or 0.9 mm).

5.2.1.3 Base frame 16 USSG (0.0598 in. or 1.5 mm).

5.3 Joining of Metal Components:

5.3.1 Metal components shall be joined by welding or gluing with a structural adhesive as defined in Terminology D 907. The back panel may be riveted to case provided rivets are not visible after installation.

5.3.2 Joining shall be adequate to prevent racking of chest during handling.

5.3.3 Spotwelds shall be spaced approximately 3 in. (76 mm) on centers.

5.3.4 Visible spotwelds, higher than the general surface of the adjacent metal, shall be ground flush.

1 This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.


2 Annual Book of ASTM Standards, Vol 01.03.

3 Annual Book of ASTM Standards, Vol 15.06.

4 Annual Book of ASTM Standards, Vol 01.07.

5 Available from the American Institute of Steel Construction, One E. Wacker Dr., Chicago, IL 60601–2001.
5.3.5 Visible spotweld depressions shall be spot filled and sanded flush.

5.4 Side panels shall be stiffened suitably to prevent buckling or oil-canning.

5.5 Sounddeadening shall be vermin proof and applied to back and inner face of sides of chest. Location and thickness of applied sound deadener shall be as required to sound-deaden chest.

5.6 Top shall be manufactured in accordance with Specification F 826.

5.7 Drawers shall be manufactured in accordance with Specification F 825.

5.8 Doors shall be Type I, Grade A and shall be manufactured in accordance with Specification F 782.

5.9 Cabinet section shall be provided with two adjustable shelves.

5.10 Top shall be provided with a pencil tray along back edge.

5.11 A furniture base shall be provided suitable for securing log desk to deck.

6. Performance Requirements

6.1 The completed log desk with cabinet, with top, drawers, and doors installed, shall satisfy the corresponding performance requirements outlined in Specifications F 826, F 825, and F 782.

6. Performance Requirements

7. Dimensions

7.1 For dimensions, see Table 1.

8. Workmanship, Finish, and Quality Assurance

8.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice so as to produce each item suitable for its intended use.

8.2 All exposed burrs, raw or sharp edges which might be injurious to personnel shall be removed.

8.3 Depressions considered unacceptable for product’s end use shall be spot filled and sanded smooth.

8.4 Finish:

8.4.1 All steel surfaces unless corrosion resistant or with a corrosion-resistant plating shall be painted so as to prevent corrosion.

8.4.2 Unless otherwise required by the ordering documents, all parts normally visible on the completed unit shall have the manufacturer’s standard baked-on enamel finish.

8.4.3 Color to be specified in the ordering documents.

9. Inspection and Certification

9.1 Manufacturer shall inspect and certify that the item of furniture complies with the furniture specification and the loading requirements as defined in Section 6.
10. Packaging and Package Marking

10.1 Each item shall be marked in accordance with the purchase order.

10.2 Packaging shall be provided and shall be acceptable to a common carrier.

11. Keywords

11.1 cabinets; log desks; marine furniture; marine log desks; steel log desks

---

**TABLE 1 Dimensions of Log Desk with Cabinet**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Dimension</th>
<th>Tolerance To + Or −</th>
<th>Dimension</th>
<th>Tolerance To + Or −</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width A</td>
<td>30</td>
<td>1/16</td>
<td>762</td>
<td>2</td>
</tr>
<tr>
<td>Height B</td>
<td>42</td>
<td>1/16</td>
<td>1087</td>
<td>2</td>
</tr>
<tr>
<td>Depth C</td>
<td>24</td>
<td>1/16</td>
<td>610</td>
<td>2</td>
</tr>
<tr>
<td>Drawer section overhang D</td>
<td>5 5/8</td>
<td>1/16</td>
<td>143</td>
<td>2</td>
</tr>
<tr>
<td>Toespace, front, E</td>
<td>3</td>
<td>max</td>
<td>76 max</td>
<td>2</td>
</tr>
<tr>
<td>Toespace, side, F</td>
<td>4 max</td>
<td>1/16</td>
<td>102 max</td>
<td>2</td>
</tr>
<tr>
<td>Drawer section height G</td>
<td>7 max</td>
<td>1/16</td>
<td>178 max</td>
<td>2</td>
</tr>
<tr>
<td>Base height H</td>
<td>4 3/4 max</td>
<td>1/16</td>
<td>121 max</td>
<td>2</td>
</tr>
</tbody>
</table>

*If log desk is located in a corner, Dimension F next to this adjacent wall shall be 0 in. (0 mm). In all other cases, the minimum value for Dimension F shall be 3/4 in. (19 mm).*

*The minimum value for Dimension H shall be 4 in. (120 mm).*

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Standard Specification for
Tables, Mess, Marine, Steel

1. Scope
1.1 This specification covers the construction of round, square, and rectangular marine mess tables with or without adjustable lee rails for use in crew, officer, and passenger dining areas aboard ship.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents, given in parentheses, are provided for information only.

2. Referenced Documents
2.1 ASTM Standards:
A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
A 240/A 240M Specification for Heat-Resisting Chromium and Nickel-Chromium Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled
A 500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
A 501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
A 567/A 567M Specification for Castings, Iron, Cobalt, and Nickel-Base Alloy, for High Strength at Elevated Temperatures
A 569/A 569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
D 907 Terminology of Adhesives

2.2 National Electrical Manufacturer’s Association:
NEMA LD-3 High Pressure Decorative Laminates

2.3 American Institute of Steel Construction Manual:
AISC Wire and Sheet Metal Gages—Equivalent Thickness in Decimals of an Inch, U.S. Standard Gage (USSG) for Uncoated Hot and Cold Rolled Sheets

3. Terminology
3.1 Definitions of Terms Specific to This Standard:
3.1.1 mess table—a dining table for use in crew, officer, or passenger dining areas, consisting of a horizontal top assembly and one or more supporting pedestals.
3.1.2 table top—the assembled horizontal surface of the mess table including the substrate, top covering, lee rails, and edge binder, or all of the preceding.
3.1.2.1 substrate—the structural core of the top assembly.
3.1.2.2 top covering—the decorative melamine laminate attached to the top surface of the substratae.
3.1.2.3 Lee Rails:
(a) fixed lee rail—a trim piece at the edge of the table top that projects above the upper surface of the table top to retain tableware and act as an edge binder.
(b) adjustable lee rail—a trim piece at the edge of the table top that can be raised above the upper surface of the table top to retain tableware and can be retracted when not needed.
3.1.2.4 edge binder—the finishing strips of metal applied to the edge of the table top.
3.1.2.5 cleanout—an interruption in the raised portion of the lee rail to facilitate cleaning of table top.
3.1.2.6 pedestal—a round or square tubular column, or stanchion, that supports the table top. Each pedestal has a table-support plate at its upper end and provisions at the bottom for attaching to the structural deck.
(a) table support plate—a flanged, dished plate or flat plate with gussets welded to top of pedestal for supporting and attaching to the table top.
3.1.2.7 deck socket—a metal sleeve or adaptor welded to the structural deck, over which the table pedestal is installed and attached.

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4. Classification

4.1 Types:

4.1.1 Type I—Round mess table with single pedestal.
4.1.2 Type II—Square mess table with single pedestal.
4.1.3 Type III—Rectangular mess table.
4.1.3.1 Grade I—Rectangular table with single pedestal.
4.1.3.2 Grade 2—Rectangular table with two pedestals.
4.2 Classes:

4.2.1 Class A—Table with fixed lee rails.
4.2.2 Class B—Table with adjustable lee rails.

5. Ordering Information

5.1 Orders for materials under this specification shall include the following:

5.1.1 Quantity and size of each type, grade, and class.
5.1.2 Paint:
5.1.2.1 Color—The purchaser shall pick from manufacturer's samples or submit a sample chip of color desired.
5.1.2.2 Manufacturer's standard baked enamel will be furnished unless otherwise required and indicated by the purchaser.
5.1.3 Color or pattern of melamine laminate top covering.
5.1.4 If pedestal deck sockets are required, they shall be specified in the ordering document; otherwise, the table manufacturer shall have the option of supplying pedestals without sockets but with 2 in. (51 mm) of scribing for trimming and welding to the deck on the ship.
5.1.5 If the total weight of the table assembly is required, it shall be requested by the purchaser.

6. Materials and Manufacture

6.1 For typical design, see Fig. 1, Fig. 2, and Fig. 3.

6.2 Tops:

6.2.1 Tops shall be steel construction with a decorative melamine laminate top cover. The minimum thickness for the top plate, stiffener, and edge channels shall be 16 USSG (0.0598 in. or 1.50 mm) and made from cold-rolled steel sheet of commercial quality in accordance with Specification A 366/A 366M.

6.2.2 The top cover shall be a high-pressure melamine laminate in accordance with NEMA Specification LD-3 with a maximum thickness of \( \frac{1}{16} \) in. (2 mm) securely bonded to the top plate.

6.2.3 Lee Rails, Fixed and Adjustable, shall be anodized aluminum alloy 6063-T1 in accordance with Specification B 221. Studs for attaching to table top shall be Type 300 stainless steel in accordance with Specification A 582/A 582M.

6.2.4 Edge Binder for Tables with Adjustable Lee Rails, shall be flush with top of table and may be either anodized aluminum alloy 6063-T1 in accordance with Specification B 221 or polished Type 300 stainless steel in accordance with Specification A 240/A 240M, at the option of table manufacturer.

6.2.5 Cleanouts, shall be provided as indicated in Figs. 1-3.

6.3 Pedestals:

6.3.1 Pedestal quantity and sizes shall be as specified in Tables 1-6 as illustrated in Figs. 1-3. Commercially acceptable tolerances as specified in Specifications A 53/A 53M, A 500, or A 501 shall apply to all pedestal dimensions. Pedestals shall be of either welded or seamless construction. The choice of round or square pedestal shall be at the option of the table manufacturer. Round pedestals shall be black steel pipe in accordance with Specification A 53/A 53M. Square pedestals shall be structural-steel tubing in accordance with Specifications A 500 or A 501.

6.3.2 Table Support Plate, may be either a flanged dished plate or a flat plate with gussets. If a flat plate and gussets, it shall be of hot-rolled, commercial-quality steel pickled and oiled in accordance with Specification A 567/A 567M and with a minimum thickness of 7 USSG (0.1793 in. or 5 mm). For dished plate, it shall be cold-rolled steel sheet of commercial quality in accordance with Specification A 366/A 366M and with a minimum thickness of 14 USSG (0.0747 in. or 2 mm).

6.3.3 Pedestals may be attached to the deck by welding or by attaching to deck socket. Unless specified in the ordering document, the method used is at the option of the table manufacturer. If round pedestals and sleeves are used, provisions must be made to ensure that the table will not turn.

6.4 Joining:

6.4.1 Metal Components, shall be joined by welding or gluing with a structural adhesive as defined in Terminology D 907.

6.4.2 Joining shall be adequate to prevent racking during manufacture or service.

6.4.3 Spotwelds, shall be spaced approximately 3 in. (76 mm) on centers.

6.4.4 Visible Spotwelds, higher than the general surface of the adjacent metal, shall be ground smooth.

6.4.5 Visible Spotweld Depressions, shall be spot filled and ground flush.

7. Performance Requirements

7.1 Tops for mess tables shall be capable of supporting a load of 400 lb (181 kg) uniformly distributed over an area of 2 ft² (0.12 m²) and placed at any location on the top. Load shall remain on top for a minimum of 3 min, and there shall be no indication of permanent set after removal of load.

8. Dimensions

8.1 For dimensions of tables and pedestals, see Figs. 1-3 and Tables 1-6.

9. Workmanship, Finish, And Appearance

9.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice so as to produce each item suitable for its intended use.

9.2 All exposed burrs, raw, or sharp edges which might be injurious to personnel shall be removed.

9.3 Depressions considered unacceptable for the product’s end use shall be spot filled and sanded flush.

9.4 Finish:

9.4.1 All steel surfaces, unless corrosion resistant or with a corrosion-resistant plating, shall be painted so as to prevent corrosion.
9.4.2 Unless otherwise required by the ordering documents, all normally visible parts of the completed unit shall have the manufacturer’s standard baked-on enamel finish.

9.4.3 Color to be specified in the ordering documents.

10. Inspection and Certification

10.1 The manufacturer shall inspect and certify that the item of furniture complies with the furniture specification and the loading requirements as defined in Section 7.

11. Packaging And Package Marking

11.1 Each item shall be marked in accordance with the purchase order.
11.2 Packaging shall be provided and shall be acceptable to a common carrier.

12. Keywords

12.1 marine furniture; marine mess tables; mess tables; ship dining areas
Note 1—See Notes 1 through 7 under Fig. 1.

FIG. 2 Square Mess Table (Type II)
Note 1—See Notes 1 through 7 under Fig. 1.

**FIG. 3 Rectangular Mess Table (Type III)**

**TABLE 1 Miscellaneous Dimensions—Round Table**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Dimension</th>
<th>Tolerance</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table height</td>
<td>A</td>
<td>29</td>
<td>736</td>
<td>2</td>
</tr>
<tr>
<td>Table diameter</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanout (typical)</td>
<td>C</td>
<td>3</td>
<td>76</td>
<td>2</td>
</tr>
<tr>
<td>Stud locations</td>
<td>D</td>
<td>4</td>
<td>102</td>
<td>2</td>
</tr>
</tbody>
</table>
### TABLE 2 Table and Pedestal Sizes—Round Table

<table>
<thead>
<tr>
<th>Outside Diameter, in. (mm)</th>
<th>Tolerances, in. (mm)</th>
<th>Round Table Size (B)</th>
<th>Pedestal Size (See Note 1 and Note 2)</th>
<th>Round Steel Pipe (See Note 3)</th>
<th>Square Steel Tubing (See Note 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nominal Size</td>
<td>Outside Diameter, in. (mm)</td>
<td>Wall Thickness, in. (mm)</td>
<td>Dimension Across Flat Side, in. (mm)</td>
</tr>
<tr>
<td>36 (914)</td>
<td>¼ (2)</td>
<td>4 in.</td>
<td>4¼ (114)</td>
<td>0.237 (6)</td>
<td>4 by 4 (102 by 102)</td>
</tr>
<tr>
<td>48 (1219)</td>
<td>¼ (2)</td>
<td>6 in.</td>
<td>6¼ (168)</td>
<td>0.280 (7)</td>
<td>6 by 6 (152 by 152)</td>
</tr>
<tr>
<td>60 (1524)</td>
<td>¼ (2)</td>
<td>8 in.</td>
<td>8¼ (219)</td>
<td>0.322 (8)</td>
<td>8 by 8 (203 by 203)</td>
</tr>
</tbody>
</table>

### TABLE 3 Miscellaneous Dimensions—Square Table

<table>
<thead>
<tr>
<th>Designation</th>
<th>in.</th>
<th>mm</th>
<th>Dimension Tolerance</th>
<th>Dimension Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table height</td>
<td>A</td>
<td>29</td>
<td>¼ (6)</td>
<td>736</td>
</tr>
<tr>
<td>Table size</td>
<td>B</td>
<td>30</td>
<td>¼ (6)</td>
<td>762</td>
</tr>
<tr>
<td>Cleanout (typical)</td>
<td>C</td>
<td>2</td>
<td>¼ (6)</td>
<td>51</td>
</tr>
<tr>
<td>Stud locations</td>
<td>D</td>
<td>4</td>
<td>¼ (6)</td>
<td>102</td>
</tr>
</tbody>
</table>

### TABLE 4 Table and Pedestal Sizes—Square Table

<table>
<thead>
<tr>
<th>Dimension Of Sides, in. (mm)</th>
<th>Tolerances, in. (mm)</th>
<th>Square Table Size (B)</th>
<th>Pedestal Size (See Note 1 and Note 2)</th>
<th>Round Steel Pipe (See Note 3)</th>
<th>Square Steel Tubing (See Note 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 by 30</td>
<td>¼ (2)</td>
<td>4 in.</td>
<td>4¼ (114)</td>
<td>0.237 (6)</td>
<td>4 by 4 (102 by 102)</td>
</tr>
<tr>
<td>(762 by 762)</td>
<td></td>
<td>Schedule 40</td>
<td>6¼ (168)</td>
<td>0.280 (7)</td>
<td>6 by 6 (152 by 152)</td>
</tr>
<tr>
<td>36 by 36</td>
<td>¼ (2)</td>
<td>6 in.</td>
<td>6¼ (168)</td>
<td>0.280 (7)</td>
<td>6 by 6 (152 by 152)</td>
</tr>
<tr>
<td>(914 by 914)</td>
<td></td>
<td>Schedule 40</td>
<td>8¼ (219)</td>
<td>0.322 (8)</td>
<td>8 by 8 (203 by 203)</td>
</tr>
</tbody>
</table>

### TABLE 5 Miscellaneous Dimensions—Rectangular Table

<table>
<thead>
<tr>
<th>Designation</th>
<th>in.</th>
<th>mm</th>
<th>Dimension Tolerance</th>
<th>Dimension Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table height</td>
<td>A</td>
<td>29</td>
<td>¼ (6)</td>
<td>736</td>
</tr>
<tr>
<td>Table width</td>
<td>B</td>
<td>30</td>
<td>¼ (6)</td>
<td>762.0</td>
</tr>
<tr>
<td>Table length</td>
<td>C</td>
<td>2</td>
<td>¼ (6)</td>
<td>51</td>
</tr>
<tr>
<td>Corner cleanouts</td>
<td>D</td>
<td>3</td>
<td>¼ (6)</td>
<td>76</td>
</tr>
<tr>
<td>Side cleanouts</td>
<td>E</td>
<td>4</td>
<td>¼ (6)</td>
<td>102</td>
</tr>
<tr>
<td>Stud locations</td>
<td>F</td>
<td>24</td>
<td>¼ (6)</td>
<td>610</td>
</tr>
</tbody>
</table>

| Pedestal location | G  | 24  | ¼ (6)               | 610                 | 2                  |
### TABLE 6  Table and Pedestal Sizes—Rectangular Table

<table>
<thead>
<tr>
<th>Grade</th>
<th>Length, in. (mm)</th>
<th>Tolerance, in. (mm)</th>
<th>Nominal Size</th>
<th>Outside Diameter, in. (mm)</th>
<th>Wall Thickness, in. (mm)</th>
<th>Dimension Across Flat Side, in. (mm)</th>
<th>Wall Thickness, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48 (219)</td>
<td>1/16 (2)</td>
<td>6 in.</td>
<td>6 1/4 (168)</td>
<td>0.280 (7)</td>
<td>6 by 6</td>
<td>0.250 (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Schedule 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>72 (1829)</td>
<td>1/16 (2)</td>
<td>4 in.</td>
<td>4 1/2 (114)</td>
<td>0.237 (6)</td>
<td>4 by 4</td>
<td>0.250 (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Schedule 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>96 (2348)</td>
<td>1/16 (2)</td>
<td>4 in.</td>
<td>4 1/2 (114)</td>
<td>0.237 (6)</td>
<td>4 by 4</td>
<td>0.250 (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Schedule 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>120 (3048)</td>
<td>1/16 (2)</td>
<td>4 in.</td>
<td>4 1/2 (114)</td>
<td>0.237 (6)</td>
<td>4 by 4</td>
<td>0.250 (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Schedule 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Standard Specification for Drawers, Furniture, Marine, Steel

This standard is issued under the fixed designation F 825; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the construction of steel furniture drawers for use where invoked by other marine furniture specifications.

1.2 This specification applies to all furniture drawers, except items requiring progressive drawers.

1.3 Values stated in inch-pound units are to be regarded as the standard. The metric equivalents, given in parentheses, are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled

A 526/A 526M Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality

D 907 Terminology of Adhesives

2.2 American Institute of Steel Construction Manual:

AISC Wire and Sheet Metal Gages— Equivalent Thickness in Decimals of an Inch, U.S. Standard Gage for Uncoated Hot and Cold Rolled Sheets

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 drawers—storage units in furniture items that have tracks on the sides to allow the drawer to slide open or closed.

3.1.2 tracks—the supporting assembly, attached to the sides of a drawer, that allows a drawer to slide open or closed.

3.1.3 drawer tracks—that portion of the track assembly that is attached to drawer sides.

3.1.4 case track—that portion of the track assembly that is attached to side of supporting furniture (case) item.

4. Ordering Information

4.1 Drawers are included as part of the orders for items of furniture requiring drawers. These orders shall include the following:

4.1.1 Paint:

4.1.1.1 Color—Drawers shall be painted to match the furniture item in which they are installed.

4.1.1.2 Manufacturer’s standard baked enamel will be furnished unless otherwise required and indicated by the purchaser.

4.1.2 Locks, if required, shall be installed where noted in the ordering documents.

5. Materials And Manufacture

5.1 For typical design, see Fig. 1.

5.2 Joining:

5.2.1 Metal Components of Drawers, shall be joined by welding or gluing with a structural adhesive as defined in Terminology D 907.

5.2.2 Joining shall be adequate to prevent racking during handling.

5.2.3 Spotwelds, shall be spaced approximately 3 in. (76 mm) on centers.

5.2.4 Visible Spotwelds, on the exterior face of drawer front, higher than the general surface of the metal, shall be ground flush.

5.2.5 Visible Spotweld Depressions, on the exterior face of drawer front, shall be spot filled and sanded flush.

5.3 Drawer Front, body and back a minimum of 20 USSG (0.0359 in. or 0.90 mm) in accordance with Specification A 366/A 366M.

5.4 Drawer Locks, if required, shall be disk tumbler cam locks having 90° rotation with a screw-on or spun-on cap attachment. Cylinders shall be die-cast zinc with exposed surfaces finished in satin nickel-plated US-15 finish.

5.5 Drawers, shall be equipped with a means for stopping the drawer at fully extended position. In this fully extended position, the drawer shall project into the supporting furniture...
unit no more than 6 in. (152 mm) for drawers 20 in. (508 mm) long and over and 5 in. (127 mm) for drawers less than 20 in. (508 mm).

5.6 All drawers shall incorporate a latch or other positive means to prevent drawers opening in heavy seas. Spring, bullet, magnetic, or bayonet-type catches will not be permitted. Furniture drawers shall not open when the furniture unit in which drawer is installed is tilted a maximum of 30° from the vertical with a drawer load of 30 lb (14 kg).

5.7 All drawers shall be furnished with a means for pulling drawers open.

5.8 **Drawer and Case Tracks:**

5.8.1 Each drawer shall have a pair of drawer tracks with one drawer track on each of its sides. The supporting furniture (case) shall incorporate case tracks on each side to support drawer track.

5.8.2 Drawer and case tracks shall be zinc-coated steel in accordance with Specification A 526/A 526M, a minimum of 18 USSG (0.0478 in. or 1.22 mm). They shall be equipped with antifriction devices, such as nylon buttons, on horizontal bearing surfaces to minimize friction.

6. **Performance Requirements**

6.1 **Load Requirement:**

6.1.1 Unless otherwise specified, all drawers 30 in. and below (762 mm and below) in length shall safely support a load of 300 lb (136 kg). The load requirement does not apply to drawers with lengths over 30 in. (over 762 mm).

6.1.2 These loads shall be applied to the front edge of the drawer, with the drawer fully extended to the drawer stop position. Load shall remain on drawer for 3 min.

6.1.3 This test shall not adversely affect the operation of the drawer, and no indication of permanent set shall exist after removal of load. Brinelling, or crushing of replaceable nylon buttons in track assembly, shall not constitute failure under this test.

6.2 **Tilt Test:**

6.2.1 Drawers shall be checked against sliding open in a tilted attitude by randomly placing 30 lb (14 kg) of books in the drawer. The item of furniture shall then be tilted 30° from the vertical and maintained in this position for 3 min. During this time, the drawer must remain closed.

7. **Dimensions**

7.1 Drawers shall be made to a size that suits the furniture item that supports them.

8. **Workmanship, Finish, And Appearance**

8.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice to produce each item suitable for its intended use.

8.2 All exposed burrs, raw, or sharp edges that might be injurious to personnel shall be removed.
8.3 Depressions considered unacceptable for the product’s end use shall be spot filled and sanded smooth.

8.4 Finish:

8.4.1 All steel surfaces, unless corrosion resistant or with a corrosive-resistant plating, shall be painted so as to prevent corrosion.

8.4.2 Unless otherwise required by the furniture specification, all normally visible parts of the completed unit shall have the manufacturer’s standard baked-on enamel finish.

9. Inspection And Certification

9.1 Inspection and certification requirements of the furniture item in which the drawer or drawers is installed shall govern.

10. Packaging And Package Marking

10.1 Each drawer shall be installed in its respective furniture item before shipment. Marking and packaging requirements of the furniture item shall govern.

11. Keywords

11.1 drawers; marine furniture; steel furniture drawers

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1. Scope

1.1 This specification covers the construction of steel furniture tops for use where invoked by other marine furniture specifications.

1.2 This standard applies to tops for furniture case goods only such as chests of drawers, log desks with cabinets, and so forth.

1.3 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents, given in parentheses, are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled
B 16/B 16M Specification for Free-Cutting Brass Rod, Bar and Shapes For Use in Screw Machines
B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
D 907 Terminology of Adhesives
2.2 National Electrical Manufacturer’s Association:
ANSI/NEMA LD-3 High Pressure Decorative Laminates
2.3 American Institute of Steel Construction Manual:
AISC Wire and Sheet Metal Gages—Equivalent Thickness in Decimals of an Inch, U.S. Standard Gage for Uncoated Hot And Cold Rolled Sheets
2.4 American National Standards Institute Standard:
A208.1 American National Standard for Mat Formed Particle Board

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 case goods—furniture items having drawers, a cabinet with doors, or both.
3.1.2 edge binder—the strips of metal or other material applied to the edges of a top.
3.1.3 lee rails—extensions above the surface of furniture tops that retain items placed on top.
3.1.4 substrate material—the core, or structural material of the top, to which the melamine laminate is directly bonded.
3.1.5 tops—the horizontal surface that makes up the upper exposed surface of furniture items.

4. Classification

4.1 Tops shall be of the following types as required by the specifications for the item of furniture and as indicated in the ordering documents. See Fig. 1, Fig. 2, Table 1, and Table 2 for details.

4.1.1 Type I—Top on which the edge binder is flush with the top and the substrate material is steel.
4.1.2 Type II—Top on which the edge binder projects above the upper surface of the top to act as a lee rail and the substrate material is steel.
4.1.3 Type III—Top on which a lee rail is applied to the upper surface of the finished top, the top has a self edge securely bonded to the finished top, and the substrate material is a particle or mineral board core.
4.1.4 Type IV—Top is an insert panel and the edge binder is an integral part of the supporting furniture unit.

4.1.4.1 Grade 1—Substrate material and edge reinforcements for Types I, II, and IV Grade 1 tops shall be a minimum of 16 USSG (0.0598-in. or 1.6-mm) steel in accordance with Specification A 366/A 366M.
4.1.4.2 Grade 2—Substrate material is a particle or mineral board core with a minimum density of 45 lb/ft³ (722 kg/m³).

5. Ordering Information

5.1 Tops are included as part of the orders for items of furniture requiring tops. These orders shall include the following information:
5.1.1 Type.
5.1.2 Color or pattern of top covering material, or both.
5.1.3 If Type III top is ordered, whether lee rail is required.

6. Materials and Manufacture

6.1 For typical design, see Fig. 1 and Fig. 2.

6.2 Sheet Metal, shall be cold-rolled steel, commercial quality, furniture grade in accordance with Specification A 366/A 366M.

6.3 Joining:
6.3.1 Metal components shall be joined by welding or gluing with a structural adhesive as defined in Terminology D 907.

6.3.2 Joining shall be adequate to prevent racking during handling.

6.3.3 Spotwelds, shall be spaced approximately 3 in. (76 mm) on centers.

6.3.4 Visible Spotwelds, higher than the general surface of the metal, shall be ground flush.

6.3.5 Spotweld Depressions, shall be spot filled and sanded flush.

6.4 Top Covering for All Type Tops, shall be high-pressure melamine laminate in accordance with ANSI/NEMA LD-3, with a minimum thickness of 0.045 in. (1.1 mm) and a maximum thickness of 0.062 in. (1.6 mm) securely bonded to upper surface of substrate material.

6.5 Completed Top, shall be securely attached to the supporting furniture unit below.

6.6 Type I also has the following requirements:

6.6.1 Substrate, a minimum of 16 USSG (0.0598 in. or 1.50 mm) of steel in accordance with Specification A 366/A 366M.
6.6.2 *Edge Reinforcement*, shall be a minimum of 16 USSG (0.0598 in. or 1.50 mm) of steel in accordance with Specification A 366/A 366M.

6.6.3 For Types I, II, and IV Grade 1 tops, a stiffener shall be applied to any area of the steel substrate having an unsupported width >3½ in. (>89 mm). Stiffener shall be 18 USSG (0.0478 in. or 1.20 mm) in accordance with Specification A 366/A 366M. See Fig. 3 for a definition of this requirement.

6.6.4 *Edge Binder*, for Type I top shall be of Type 6063-TI anodized aluminum extrusion in accordance with Specification B 221 and installed flush with the upper surface of the finished top.

6.6.5 *Back Molding*, shall be an anodized aluminum extruded bar in accordance with Specification B 221, attached to the top with No. 6 oval head stainless steel machine screws.

6.7 Type II also has the following requirements:

6.7.1 Substrate in accordance with 6.6.1.

6.7.2 Edge reinforcement in accordance with 6.6.2.

6.7.3 Substrate stiffener in accordance with 6.6.3.

6.7.4 *Combination Edge Binder and Lee Rail*, shall be of Type 6063-TI anodized aluminum-alloy extrusion in accordance with Specification B 221 and installed so it projects above the upper surface of top a minimum of ¼ in. (6.35 mm) to act as a lee rail.

6.7.5 Back molding in accordance with 6.6.5.

6.8 Type III also has the following requirements:

6.8.1 *Substrate*, shall be particle board core in accordance with ANSI A208.1, or mineral board core, maximum thickness of 1 in. (25.4 mm).

6.8.2 *Self Edge*, of the same material as the melamine top covering shall be securely bound to the top edge. Where tops have radiused edges requiring a postforming grade of the melamine laminate, a black color may be used if a top matching color or pattern in postforming melamine laminate is not available.

6.8.3 *Lee Rail of Polished and Lacquered Brass*, in accordance with Specification B 16/B 16M shall be applied to upper surface of finished top after application of melamine covering and shall project above the upper surface of the top a maximum of ¼ in. (6 mm).

6.8.4 Types III and IV Grade 2 tops shall have a backing sheet securely bonded to the underside of particle board substrate material. The backing sheet shall be a ANSI/NEMA LD-3 Type BK30 or BK40 high-pressure back laminate.

6.9 Type IV, Grade 1 also has the following requirements:

6.9.1 Substrate in accordance with 6.6.1.

6.9.2 Edge reinforcement in accordance with 6.6.2.

6.9.3 Substrate stiffener in accordance with 6.6.3.

6.9.4 The top is an inserted panel and the edge binder is an integral part of the supporting furniture unit. The edge binder, except for rear molding, is 18 USSG steel (0.0478 in. or 1.20 mm) in accordance with Specification A 366/A 366M.

6.9.5 The back molding shall be in accordance with 6.6.5.

6.10 Type IV, Grade 2 also has the following requirements:

6.10.1 *Substrate*, shall be particle board core in accordance with ANSI A208.1 or mineral board core, ½ in. (13 mm) thick.

6.10.2 Binder in accordance with 6.9.4.

6.10.3 Backing sheet in accordance with 6.8.4.

6.10.4 Back molding in accordance with 6.6.5.

6.11 Type IV Grades 1 and 2 tops shall be retained in case with No. 8 hex head jack screws and lock nuts spaced 8 in. (203 mm) on center. The completed top shall be attached securely to the supporting furniture unit below.

7. **Performance Requirements**

7.1 Tops shall be capable of supporting a load of 400 lb (181 kg) uniformly distributed over an area of 2 ft² (0.2 m²) and placed at any location on the top. Load shall remain on top for a minimum of 3 min, and there shall be no indication of permanent set after removal of load.

8. **Dimensions**

8.1 Tops shall be made to a size that suits the furniture item that supports them.

8.2 Lee rails shall not extend above the upper surface of the finished top more than ¼ in. (6 mm).

9. **Workmanship, Finish and Appearance**

9.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice to produce each item suitable for its intended use.

9.2 All exposed burrs, raw, or sharp edges which might be injurious to personnel shall be removed.

9.3 Depressions considered unacceptable for product’s end use shall be spot filled and sanded smooth.

9.4 Plastic laminate shall be well bonded to top substrate and shall have no loose edges.

9.5 All tops shall be flat.

9.6 *Finish*:

9.6.1 All steel surfaces, unless corrosion resistant or with a corrosion-resistant plating, shall be painted so as to prevent corrosion.

9.6.2 Unless otherwise required by the furniture specification, all normally visible parts of completed unit shall have the manufacturer’s standard baked-on enamel finish.

9.6.3 Color and pattern to be specified in the ordering documents.

10. **Inspection And Certification**

10.1 Inspection and certification requirements of the furniture item on which the top is installed shall govern.

11. **Packaging And Package Marking**

11.1 Each top shall be installed in its respective furniture item before shipment. Marking and packaging requirements of furniture item shall govern.
12. Keywords

12.1 cabinets; furniture case goods; furniture tops; log
desks; marine; marine furniture; ship; steel furniture tops

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Standard Specification for
Ladders, Fixed, Vertical, Steel, Ship’s

This standard is issued under the fixed designation F 840; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers fabrication details for fixed,
vertical, steel ladders for personnel access on ships.
1.2 Nonferrous ladders and special-purpose ladders are
excluded from this specification.
1.3 The values stated in inch-pound units are to be regarded
as the standard.
1.4 This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
priate safety and health practices and determine the applica-
bility of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards: 2
A 36/A36M Specification for Carbon Structural Steel
2.2 American Bureau of Shipping, Rules for Building and
Classing Steel Vessels: 3
Section 43.3 Ordinary Strength Hull Structural Steel
Section 30 Welding
2.3 American Welding Society Standard: 4
AWS D 1.1—Structural Welding Code
2.4 Federal Standard: 5
TT-P-645 Primer, Paint, Zinc Chromate, Alkyd Type

3. Definition of Terms Specific to This Standard

3.1 fixed ladder—a ladder permanently attached by welding
or bolting to ship’s structure or equipment.
3.2 pitch—the included angle between the horizontal and
the ladder, measured on the opposite of the ladder from the
climbing side.
3.3 vertical ladder—a ladder which has an installed pitch
range from 75 to 90° (vertical).

4. Classification

4.1 Ladders are furnished in three types as follows:
4.1.1 Type I—Normal duty (Fig. 1).
4.1.2 Type II—Punched stringers (Fig. 2) as an alternate to
Type I.
4.1.3 Type III—Heavy duty (Fig. 3). This type may be
specified in cargo holds where the cargo or equipment or
vehicles used to handle cargo could be expected to damage a
Type I or Type II ladder.

5. Ordering Information

5.1 Orders for material under this specification shall include
the following:
5.1.1 Quantity,
5.1.2 Type (4.1), and applicable detail in Fig. 2,
5.1.3 Material (6.1),
5.1.4 Finish (8.2),
5.1.5 Dimensions a and b and L (Fig. 1, Fig. 2, or Fig. 3),
5.1.6 Number of rungs,
5.1.7 Welding specification (6.2),
5.1.8 Marking (Section 10), and
5.1.9 ASTM designation and date of issue.

6. Materials and Manufacture

6.1 Unless otherwise specified in ordering documents, steel
shall conform to the requirements of Specification A 36/
A 36M, ABS Section 43.3, or equal.
6.2 Unless otherwise specified in ordering documents,
welding shall conform to AWS D 1.1 or ABS Section 30.

7. Dimensions

7.1 The dimensions shall be in accordance with Figs. 1-3.
7.2 Dimensions are given in inches with metric conversion
in parentheses.

8. Workmanship, Finish, and Appearance

8.1 Ladders shall be free of splinters, sharp edges, burrs, and
weld spatters.
8.2 Finish—Unless otherwise specified in ordering docu-
ments, ladders shall, after fabrication, be sand or shot blasted
to remove rust and scale and given a complete coat of zinc
chromate primer, Federal Specification TT-P-645.
9. Inspection

9.1 Unless otherwise specified in ordering documents, all ladders shall be visually inspected for workmanship, finish, and appearance as defined in Section 8.

10. Marking

10.1 Unless otherwise specified in ordering documents, each ladder shall be marked with purchase-order number, item number (from purchase order), ASTM designation number, and manufacturer’s name. Marking may be by steel stamp, paint stencil, or weatherproof tag.

11. Keywords

11.1 fixed ladders; ladders; marine; ship; steel ladders; vertical ladders
FIG. 2 Vertical Ladder Type II (Punched Stringers) as an Alternative to Type I

NUMBER OF RUNGS, DIMENSIONS a AND b
AND OVERALL LENGTH L TO BE
AS SPECIFIED ON ORDER.

FABRICATION TOLERANCE: ± 1/4 in. (± 6.4)
FLAT BAR AND SQUARE BAR: MILL
TOLERANCE APPLIES.

FIG. 2 Vertical Ladder Type II (Punched Stringers) as an Alternative to Type I
FIG. 3 Vertical Ladder Type III (Heavy Duty)

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Standard Specification for Thrusters, Tunnel, Permanently Installed in Marine Vessels

This standard is issued under the fixed designation F 841; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification supplies general characteristics and interface details of propeller type, fixed-tunnel thruster units permanently installed in marine vessels or structures.

1.2 Values stated in either inch-pound units or SI (metric) units are to be regarded separately as standard. The values stated in each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—This specification supplies only general design, interface, and purchase information and does not include requirements for use, thruster controls, or associated equipment. The purchaser of the thruster equipment specified herein is cautioned that he must properly correlate the operating requirements with the thruster specified.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
F 25 Test Method for Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications
2.2 American Bureau of Shipping:
ABS Rules for Building and Classing Steel Vessels
2.3 ISO Document:
ISO Recommendation ISO/DIS 484/11 (Draft)

3. Definitions of Terms Specific to This Standard

3.1 thruster—a device constructed such as to provide a force or thrust of controlled variable magnitude and direction to a marine vessel or structure, usually, but not limited to, a propeller mounted within a tunnel located below water level.

3.2 fixed pitch—(FP) a propeller in which the blades are part of, or are rigidly attached to, the hub such that the propeller pitch is constant for a given radius.

3.3 controllable pitch—(CP) a propeller in which the blades are attached to a mechanism within the hub by means of bolts or fasteners, so that controlled movement of the mechanism causes the blades to change pitch in unison.

3.4 tunnel—a part of thruster assembly of circular cross section which houses structure supporting a propeller and drive mechanism.

3.5 peak power—highest horsepower developed by the prime mover, or as limited by the thruster manufacturer.

3.6 continuous duty—operation of the thruster continuously at any power range, up to manufacturer’s rating, for extended periods, but not to overlap into recommended maintenance intervals.

3.7 intermittent duty—operation of the thruster at peak power or RPM levels, or both, for periods not exceeding 1 h followed by periods of 1 h at the continuous rating or less, with total running time not exceeding 8 h in 24 h.

3.8 landing bars—permanent attachments, usually in the form of plates welded to the tunnel during manufacture, intended to provide joining facilities for deck plates or bulkheads, or both, at installation. Landing bars are neither intended to be part of the support structure for the thruster, nor provide support or transmit forces from the vessel structure to the thruster.

3.9 prime mover—the motor(s) or engine(s) providing the power to drive the thruster.

3.10 grid bars—bars installed at the tunnel entrances in the form of a mesh to prevent large objects from passing through the thruster tunnel. The area occupied by the grid bars shall not exceed 6% of the tunnel cross-sectional area.
4. Classification

4.1 Thrusters manufactured in accordance with this specification shall be identified as follows:
4.1.1 Type I—Fixed pitch.
4.1.2 Type II—Controllable pitch.
4.2 Each type of thruster may be manufactured to the following grade:
4.2.1 Grade 1—Intermittent duty for docking and navigation.
4.2.2 Grade 2—Continuous duty for stationkeeping or dynamic positioning.

5. Ordering Information

5.1 Requests for quotation and purchase orders shall specify the following (in absence of specific requirements in ordering data, the unit will be provided only as specified herein):
5.1.1 Description of thruster.
5.1.2 ASTM designation and date of issue.
5.1.3 Type.
5.1.4 Grade.
5.1.5 Input Shaft Angle—Refer to Fig. 1.
5.1.6 Tunnel Extensions—Refer to Fig. 2.

Note 1—The thruster will be supplied without the blade hatch unless otherwise specified in the ordering data.

FIG. 1 Input Shaft Angle
5.1.7 Landing bars or other weldments to the thruster to be shown in a sketch or drawing provided by the purchaser.

5.1.8 Type of prime mover.

5.1.9 Input HP and RPM to thruster.

5.1.10 Material Options for Hub and Blades:
5.1.10.1 Ni-Al Bronze ABS Type 4.
5.1.10.2 Stainless steel Specification A 296 – 72 GR CF-3 or CF-8C or other ABS approved material.
5.1.10.3 Manganese bronze ABS Type 2.

5.1.11 Blade hatch.

5.1.12 Instruction books (unless otherwise specified, six copies in English).

5.1.13 Tunnel insert (erosion liner).

5.1.14 Painting or coating, external (water contact surfaces).

5.1.15 Painting or coating, internal (inside hull).


5.1.17 Special tools.

5.1.18 Spare parts.

5.2 As a minimum, the following vessel particulars shall be furnished when the thruster manufacturer is required to determine the thruster size; other particulars may be required by the thruster manufacturer.

5.2.1 Vessel type.

5.2.2 Applicable classification society.

5.2.3 Length at waterline.\(^6\)

5.2.4 Width at waterline.\(^6\)

5.2.5 Draft, loaded forward after or draft, ballast forward after.

5.2.6 Dimension of keel to thruster centerline.

5.2.7 Dimension of bow at waterline to thruster centerline.

5.2.8 Beam at the thruster centerline.

5.2.9 Vessel displacement.\(^6\)

5.2.10 Vessel service and operating environment.

5.2.11 Whether grid bars are to be installed.

6. Materials and Manufacture

6.1 General Requirements—The tunnel shall be made of tested steel of ABS quality or equal, fabricated, cast or forged, or a combination thereof. All structural welding shall be in accordance with the applicable regulatory agency or the thruster manufacturer’s recommendations or both. All welds exposed to (sea) water shall be overlayed with weld metal containing 2½ % nickel, minimum. The minimum tunnel

\(^6\) With reference to fully loaded design conditions.
material thickness shall meet applicable classification society requirements. A replaceable insert may be provided in the tunnel in way of the propeller tips to prevent erosion of the tunnel wall (Fig. 3). The minimum width of the insert shall be 10% of the propeller diameter. If an insert is not used, the tunnel thickness in way of the blades, and for a minimum length of 10% of the tunnel diameter, shall be increased by at least 10% of the required thickness. Reinforcement rings/stiffeners may be applied at each end of the tunnel by the manufacturer. The rings may or may not become part of the joint detail to the tunnel extension.

6.2 Propeller blades and hub may be one of the following materials or other material approved by the applicable classification society and shall be specified in the ordering data.

6.2.1 Ni-Al Bronze ABS Type 4.
6.2.2 Stainless Steel Specification A 296 – 77 GR CF-3 or CF-8C.
6.2.3 Manganese Bronze ABS Type 2.

6.3 All fasteners exposed to (sea) water shall be of monel, stainless-steel, or bronze alloy, unless otherwise specified in the ordering data.

6.4 All materials shall be free of imperfections and defects that adversely affect serviceability.

6.5 All steel surfaces exposed to (sea) water shall be cleaned, painted, or coated in accordance with manufacturer’s commercial practice or as otherwise specified in ordering data.

6.6 All steel surfaces that will be within the hull of the vessel shall be cleaned, painted, or coated in accordance with manufacturer’s commercial practice or as otherwise specified in ordering data.

6.7 The thruster shall consist of a propeller mounted within a strongly fabricated circular tunnel. The propeller will be secured to a shaft that is rigidly supported in oil lubricated antifriction bearings.

6.7.1 A thrust bearing shall be contained within a housing that is securely attached to the tunnel section such as to transmit the thrust developed by the propeller.

6.7.2 A drive mechanism shall be provided to transmit power to the propeller. This also shall be within the housing and be oil lubricated.

6.7.3 The right-angle drive shafting and propeller hub shall be removable, if necessary, for inspection or repair without removing the tunnel from the vessel.

6.7.4 The propeller shall be statistically balanced as specified in the ordering data.

6.7.5 For Type 2 controllable pitch thrusters, the tunnel may be equipped with a removable hatch over the propeller to permit withdrawal of blades. This requirement shall be specified in the ordering data.

6.8 The tunnel shall be attached to the ship’s structure by means of tubular extensions that are part of or are welded to the ends of the tunnel. No other welding on the assembled unit is permitted without the manufacturer’s approval in view of possible damage to the alignment of drive mechanism and bearings. Should other weldments, for example, landing bars, be required, they shall be specified by the purchaser before the tunnel manufacture.

6.9 A lubrication system shall be provided for bearings and gears. Seals shall be provided to prevent leakage of oil out of the thruster and ingress of (sea) water into the thruster. A pressure shall be maintained within the thruster that is at least 1 psig (7 kPa) greater than the outside water pressure measured at the thruster centerline.

7. Other Requirements

7.1 Propeller Design (General), shall be based on standard series model tests carried out at a recognized marine laboratory or by substantiated test data from previous application.

7.2 The thruster manufacturer shall submit, as a minimum, the following plans for review by the purchaser.

7.2.1 Installation drawing.
7.2.2 Outline drawings of major assemblies showing overall dimensions, interface details, and weights.

7.3 It is recommended that an hour meter be installed in the system such that preventive maintenance and records of operation may be maintained.

7.4 One Set of Special Tools, as deemed necessary by the manufacturer, for removing the propeller hub and blades, shafting and right-angle drive parts shall be provided unless otherwise stated in the ordering data.

Legend:

\( T \) = Minimum tunnel material thickness to meet applicable classification society requirements

\( D \) = Tunnel diameter (inside)

\( P \) = Propeller diameter

\( S \) = Tunnel insert (erosion liner) thickness

\( \frac{3}{16} \) in. (5 mm) minimum for \( D \leq 60 \) in. (1.52 m)

\( \frac{1}{4} \) in. (6 mm) minimum for \( D > 60 \) in. (1.52 m)

FIG. 3 Tunnel Insert (Erosion Liner) or Alternative Method
7.5 One Set of Normal Onboard Spare Parts, as recommended by the manufacturer for one year’s service shall be provided unless otherwise stated in the ordering data.

7.6 Copies of instruction books of standard commercial format shall be provided, as required by the ordering data. Instruction books shall describe the installation, startup, operation, planned maintenance, troubleshooting, assembly, and disassembly of the manufacturer’s equipment.

8. Dimensions and Ratings

8.1 Interface dimensions of thrusters shall be provided by the vendor and shall include at least the dimensions defined in Fig. 2 and Fig. 1.

8.2 At its normal continuous rating, the thruster shall be capable of producing a minimum thrust of 23 lb/hp (0.137 N/W). The input horsepower per square foot (propeller disk area) shall not exceed 50, for example, horsepower per area shall be \( \pm 50 \) (401.5 kW/m²). Propeller tip speed shall not exceed 6300 ft/min (1920 m/min).

8.3 The nominal thrust of 23 lb/hp (0.137 N/W) does not take into account losses for added tunnel length, bends, or grid bars and assumes a minimum submergence of one propeller diameter to the thruster centerline.

9. Workmanship

9.1 All workmanship shall be workmanlike and of acceptable commercial marine standard in all respects, and all materials, machinery, pieces, or parts specified shall be of recent manufacture and unused except for normal testing as required.

10. Inspection and Shop Testing

10.1 The manufacturer shall test the thruster unit to ensure proper assembly, alignment, and functioning of the internal mechanisms.

10.2 The manufacturer shall inform the purchaser at least ten days before testing such that the testing may be witnessed should the purchaser so desire.

10.3 During manufacture of the thruster, inspection records shall be made of at least the following:

10.3.1 Backlash, alignment, and pattern of gear (if used).

10.3.2 Blade tip clearances, each blade at eight equally spaced intervals.

10.3.3 For units with detachable blades, the blade weight and balance.

10.3.4 Mounting and clearance dimensions.

10.4 Final test and inspection shall include at least the following:

10.4.1 FP Units:

10.4.1.1 Spin test in air of sufficient duration to verify satisfactory operation,

10.4.1.2 Oil temperature before and during spin test, and

10.4.1.3 Visual inspection for leaks before and after spin test.

10.4.2 CP Units:

10.4.2.1 Spin test in air of sufficient duration to verify satisfactory operation,

10.4.2.2 Oil pressures and temperature before and during spin test,

10.4.2.3 Pitch changing pressures (or force if mechanical) (both directions),

10.4.2.4 Pitch changing-time full stroke, and

10.4.2.5 Visual inspection for leaks before and after spin test at relief-valve pressure operation for a period of 2 min.

10.5 Nonrotational tests shall include at least the following for CP thrusters.

10.5.1 Pitch changing time (full pitch to full pitch, both directions).

10.5.2 Minimum pitch changing pressure or force, both directions.

10.5.3 Visual leak inspection at relief-valve pressure operation for a period of 2 min.

10.5.4 Pressures during pitch cycling.

10.6 The recorded data shall be issued and become part of the instruction manual.

11. Product Marking

11.1 The thruster unit assembly shall include at least the following:

11.1.1 Manufacturer’s name,

11.1.2 Model number,

11.1.3 Serial number,

11.1.4 ASTM specification number, and

11.1.5 Date of manufacture.

12. Keywords

12.1 fixed-tunnel thrusters; propeller-type thrusters
Standard Practice for
Mechanical Symbols, Shipboard—Heating, Ventilation, and Air Conditioning (HVAC)\(^1\)

This standard is issued under the fixed designation F 856; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers symbols used on heating, ventilation, and air conditioning (HVAC) detailed engineering drawings.

1.2 These symbols may be useful on contract and preliminary design drawings.

2. Significance and Use

2.1 When symbolic representation is required for an item not covered in this standard, the character of the symbol shall be adequately identified and shall be subject to one interpretation only. If necessary, a note shall be attached to the symbol for further clarity.

2.2 Symbolic representation does not require exact or scale layouts of the actual system. Therefore, the symbols may be used in all views of the system layout.

3. Abbreviations

3.1 The abbreviations (for use only in this practice) are defined as follows:
- AF = axial fan,
- AFD = automatic fire damper with manual override,
- BD = balance damper,
- CC = cooling coil,
- CCW = counter clockwise,
- CE = convection heater, electric,
- CF = centrifugal fan,
- CS = convection heater, steam,
- CW = clockwise,
- EH = turret heater electric,
- EP = duct preheater, electric,
- ER = duct re heater, electric,
- EU = electric unit heater,
- F = filter,
- FA = flame arrester,
- FCA = fan coil assembly,
- FCU = fan coil unit,
- G = grille,
- GC = gravity cooling coil,
- H = humidistat, humidifier,
- L = louver,
- M = motor,
- MFD = manual fire damper,
- NE = natural exhaust,
- NS = natural supply,
- R = return air,
- RO = remote operated,
- SFD = solenoid fire damper,
- SP = preheater, steam,
- SR = re heater, steam,
- SU = steam unit heater,
- T = thermostat,
- TE = tempered air, electric,
- TS = tempered air, steam,
- U = undercut,
- UC = unit cooler,
- V = volume, volumetric, and
- VC = volume control.

4. Illustrations

4.1 Illustrations for HVAC symbols are given in Figs. 1-4.

5. Keywords

5.1 air conditioning; design symbols; engineering symbols; heating; HVAC; marine; ship; symbols; ventilation

\(^1\) This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.

**Note 1**—"Class A" is in reference to bulkhead classification as described in the Code of Federal Regulations, Title 46, Section 92.07-5. (Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.)

**FIG. 1 HVAC Symbols for Air Flow Ducts**

<table>
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<tr>
<th>No</th>
<th>Title</th>
<th>Symbol</th>
<th>No</th>
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</thead>
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<td>1</td>
<td>SUPPLY DUCT</td>
<td></td>
<td>11</td>
<td>DUCT - UP AND DOWN</td>
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<tr>
<td>2</td>
<td>EXHAUST DUCT</td>
<td></td>
<td>12</td>
<td>DUCT - UP AND DOWN</td>
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<td></td>
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<td></td>
<td></td>
<td>WATERPROOF OR</td>
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<td>CLASS &quot;A&quot; CONSTRUCTION (SEE</td>
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<td></td>
<td></td>
<td></td>
<td>NOTE 1)</td>
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</tr>
<tr>
<td>3</td>
<td>AIR CONDITIONING DUCT</td>
<td></td>
<td>13</td>
<td>TRUNK UP</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>RETURN AIR DUCT</td>
<td></td>
<td>14</td>
<td>TRUNK UP WATERPROOF OR</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>CLASS &quot;A&quot; CONSTRUCTION (SEE</td>
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<td>NOTE 1)</td>
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<td>5</td>
<td>WATERTIGHT OR CLASS &quot;A&quot; CONSTRUCTION DUCT (SEE NOTE 1)</td>
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<td>15</td>
<td>TRUNK DOWN</td>
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<td>6</td>
<td>FLEXIBLE CONNECTION</td>
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<td>16</td>
<td>TRUNK DOWN WATERPROOF OR</td>
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<td>DUCT UP</td>
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<td>17</td>
<td>TRUNK UP AND DOWN</td>
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<td>8</td>
<td>DUCT UP WATERPROOF OR</td>
<td></td>
<td>18</td>
<td>TRUNK UP AND DOWN</td>
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</tr>
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<td></td>
<td>CLASS &quot;A&quot; CONSTRUCTION (SEE</td>
<td></td>
<td></td>
<td>WATERPROOF OR</td>
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<td>9</td>
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<td>10</td>
<td>DUCT DOWN WATERPROOF OR</td>
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<td>1</td>
<td>Supply terminal type “E”</td>
<td><img src="image1" alt="Symbol" /></td>
<td>11</td>
<td>Watertight cover, manual or fire closure class “A” construction, manual (see note 1)</td>
<td><img src="image2" alt="Symbol" /></td>
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<td>2</td>
<td>Supply terminal down to deck</td>
<td><img src="image3" alt="Symbol" /></td>
<td>12</td>
<td>Fire damper, automatic w/ manual override</td>
<td><img src="image4" alt="Symbol" /></td>
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<tr>
<td>3</td>
<td>Supply terminal cone</td>
<td><img src="image5" alt="Symbol" /></td>
<td>13</td>
<td>Fire damper, manual</td>
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<td>4</td>
<td>Exhaust terminal down to deck</td>
<td><img src="image7" alt="Symbol" /></td>
<td>14</td>
<td>Fire damper, solenoid</td>
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<td>5</td>
<td>Exhaust terminal cone</td>
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<td>Balance damper</td>
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<td>6</td>
<td>Exhaust grille</td>
<td><img src="image11" alt="Symbol" /></td>
<td>16</td>
<td>Diverting damper</td>
<td><img src="image12" alt="Symbol" /></td>
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<td>7</td>
<td>Return air grille</td>
<td><img src="image13" alt="Symbol" /></td>
<td>17</td>
<td>Volumetric damper</td>
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<td>Diffuser</td>
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<td>Sliding damper</td>
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<td>9</td>
<td>Register</td>
<td><img src="image17" alt="Symbol" /></td>
<td>19</td>
<td>Multi-louver damper, manual operated</td>
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<tr>
<td>10</td>
<td>Air intake/discharge lift type</td>
<td><img src="image19" alt="Symbol" /></td>
<td>20</td>
<td>Multi-louver damper, motor operated</td>
<td><img src="image20" alt="Symbol" /></td>
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FIG. 2 HVAC Symbols for Duct Fittings
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<tr>
<td>21</td>
<td>Multi-Louver Damper, Motor Operated 2 Motors</td>
<td><img src="image1" alt="Symbol" /></td>
<td>31</td>
<td>Natural Supply Through Undercut Door</td>
<td><img src="image2" alt="Symbol" /></td>
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<tr>
<td>22</td>
<td>Silencer</td>
<td><img src="image3" alt="Symbol" /></td>
<td>32</td>
<td>GooseNeck</td>
<td><img src="image4" alt="Symbol" /></td>
</tr>
<tr>
<td>23</td>
<td>Watertight Closure Horizontal</td>
<td><img src="image5" alt="Symbol" /></td>
<td>33</td>
<td>Double GooseNeck</td>
<td><img src="image6" alt="Symbol" /></td>
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<td>24</td>
<td>Watertight Closure Horizontal W/ Remote Operating Gear</td>
<td><img src="image7" alt="Symbol" /></td>
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<tr>
<td>25</td>
<td>Watertight Closure Vertical</td>
<td><img src="image8" alt="Symbol" /></td>
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<td>Natural Exhaust Through Bulkhead W/ Wire Mesh</td>
<td><img src="image9" alt="Symbol" /></td>
<td></td>
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<tr>
<td>27</td>
<td>Natural Supply Through Bulkhead W/ Wire Mesh</td>
<td><img src="image10" alt="Symbol" /></td>
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<td></td>
</tr>
<tr>
<td>28</td>
<td>Natural Exhaust Through Louvered Door</td>
<td><img src="image11" alt="Symbol" /></td>
<td></td>
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</tr>
<tr>
<td>29</td>
<td>Natural Supply Through Louvered Door</td>
<td><img src="image12" alt="Symbol" /></td>
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<tr>
<td>30</td>
<td>Natural Exhaust Through Undercut Door</td>
<td><img src="image13" alt="Symbol" /></td>
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</table>

FIG. 2 HVAC Symbols for Duct Fittings (continued)
<table>
<thead>
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<th>NO</th>
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<tbody>
<tr>
<td>1</td>
<td>COWL VENTILATOR</td>
<td>![Cowl Ventilator Symbol]</td>
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<tr>
<td>2</td>
<td>NATURAL EXHAUST VENTILATOR</td>
<td>![Natural Exhaust Ventilator Symbol]</td>
</tr>
<tr>
<td>3</td>
<td>AXIAL FLOW FAN HORIZONTAL</td>
<td>![Axial Flow Fan Horizontal Symbol]</td>
</tr>
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<td>4</td>
<td>AXIAL FLOW FAN VERTICAL</td>
<td>![Axial Flow Fan Vertical Symbol]</td>
</tr>
<tr>
<td>5</td>
<td>CENTRIFUGAL FAN LEFT HAND (CW)</td>
<td>![Centrifugal Fan Left Hand Symbol]</td>
</tr>
<tr>
<td>6</td>
<td>CENTRIFUGAL FAN RIGHT HAND (CW)</td>
<td>![Centrifugal Fan Right Hand Symbol]</td>
</tr>
<tr>
<td>7</td>
<td>PROPELLER FAN</td>
<td>![Propeller Fan Symbol]</td>
</tr>
<tr>
<td>8</td>
<td>FLAME ARRESTOR</td>
<td>![Flame Arrestor Symbol]</td>
</tr>
<tr>
<td>9</td>
<td>FAN COIL ASSEMBLY</td>
<td>![Fan Coil Assembly Symbol]</td>
</tr>
<tr>
<td>10</td>
<td>FAN COIL UNIT</td>
<td>![Fan Coil Unit Symbol]</td>
</tr>
</tbody>
</table>

Note: 1—This symbol is commonly referred to as a Breidert ventilator.

FIG. 3 HVAC Symbols for Ventilators
Note 1—This symbol is commonly referred to as a Gaylord hood.

**FIG. 4 HVAC Symbols for Appliances**
Standard Specification for Envelope Dimensions for Bronze Globe Valves NPS \( \frac{1}{4} \) to 2

This standard is issued under the fixed designation F 885; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\( \varepsilon \)) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides standard dimensions for small bronze globe valves (NPS \( \frac{1}{4} \) to 2) installed in shipboard piping systems.

1.2 This specification covers valves of a nominal pipe size from NPS \( \frac{1}{4} \) to 2 with threaded and brazed end connections. The valves are in accordance with MSS-SP80, Class 200.

2. Referenced Documents

2.1 ASTM Standards:
   B2.1 Pipe Threads (Except Dryseal)\(^2\)

2.2 Manufacturer’s Standardization Society of the Valve and Fittings Industry Standard:
   SP80 Bronze Gate, Globe, Angle and Check Valves\(^3\)

3. Materials and Manufacture

3.1 Threaded end connections shall be in accordance with ANSI B2.1. Brazed end connections shall be in accordance with Table 1.

<table>
<thead>
<tr>
<th>Valve Size – NPS</th>
<th>Depth of Socket, in. (mm)</th>
<th>Diameter of Socket, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{1}{4} )</td>
<td>17/64 (7) 0.540 (13.72) 0.543 (13.79)</td>
<td></td>
</tr>
<tr>
<td>( \frac{3}{8} )</td>
<td>5/16 (8) 0.675 (17.15) 0.678 (17.22)</td>
<td></td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>3/8 (10) 0.840 (21.34) 0.843 (21.41)</td>
<td></td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>13/32 (10) 1.050 (26.76) 1.053 (26.74)</td>
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</tr>
<tr>
<td>1</td>
<td>7/16 (11) 1.315 (33.40) 1.318 (33.48)</td>
<td></td>
</tr>
<tr>
<td>1¼</td>
<td>½ (13) 1.660 (42.16) 1.663 (42.24)</td>
<td></td>
</tr>
<tr>
<td>1½</td>
<td>¼ (16) 1.900 (48.26) 1.905 (48.39)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>21/32 (17) 2.375 (60.33) 2.380 (60.45)</td>
<td></td>
</tr>
</tbody>
</table>

4. Dimensions

4.1 Valve dimensions for both threaded- and brazed-type end connections are provided in Fig. 1.

5. Tolerances

5.1 A plus or minus tolerance of \( \frac{1}{32} \) in. (0.8 mm) shall be allowed on all dimensions that do not have a maximum or minimum specified.

6. Keywords

6.1 brazed connection; bronze globe valve; envelope dimension; globe valve; marine technology; ship
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.4

4 The Supplementary Requirements shall be deleted two years from the approved date of the current edition of this specification.

S1. Permissible Variations

S1.1 The permissible variations in Dimension A of Fig. 1 are shown in Table S1.1. The permissible variations in the centerline to end dimensions for angle valves shall be one half the values specified in Table S1.1. The tolerance specified in 5.1 may be added to or deducted from Dimension ‘A’ after the permissible variation is applied.

<table>
<thead>
<tr>
<th>Valve Size – NPS</th>
<th>Permissible Variation in Dimension ‘A’</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼–%5/16</td>
<td>±5/32 (10)</td>
</tr>
<tr>
<td>1–1¼</td>
<td>±7/64 (11)</td>
</tr>
<tr>
<td>1½</td>
<td>±9/64 (14)</td>
</tr>
<tr>
<td>2</td>
<td>±1/8 (19)</td>
</tr>
</tbody>
</table>
Standard Specification for
Letters and Numerals for Ships

This standard is issued under the fixed designation F 906; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification specifies shape, size, spacing, and
shading of letters and numerals to be used aboard ship.

1.2 Characters are of Five Types:

1.2.1 Type 1—Plain letters and numerals (16 units).
1.2.2 Type 2—Block letters and numerals (12 units).
1.2.3 Type 3—Type 2 characters with shading (shading—1
unit).
1.2.4 Type 4—Block letters (10 units) and numerals (12
units).
1.2.5 Type 5—Type 4 characters with shading (shading—1
unit).

1.3 This specification does not give location or size of
various shipboard markings incorporating letters and numerals.

2. Ordering Information

2.1 When ordering letters and numerals in accordance with
this specification, it is necessary to state the ASTM designation
and the type and height of the character.

3. General Requirements

3.1 Characters are designed using the grid method which
allows the size of the character to be changed proportionately
as required.

3.1.1 Character Stroke (thickness—2 units).
3.1.2 Character Width:
3.1.2.1 Type 1, Plain Characters—12 in accordance with
Fig. 1 unless otherwise noted.
3.1.2.2 Type 2, Block Characters—8 units in accordance
with Fig. 2 unless otherwise noted.
3.1.2.3 Type 3, Block Characters with Shading—same as
Type 2 plus 1 unit for shading in accordance with Fig. 3.
3.1.2.4 Type 4, Block Characters, Letters—width varies.
Numerals—8 units.
3.1.2.5 Type 5, Block Characters with Shading—same as
Type 4 plus 1 unit for shading.

3.2 Sizing of the Character:
3.2.1 Type 1—space characters in accordance with Table 1.
3.2.2 Type 2—space characters in accordance with Table 1.
3.2.3 Type 3—space characters in accordance with Table 1
with 1 unit added to each value for shading.
3.2.4 Type 4—space letters in accordance with Fig. 4;
spacing shall be equal to the space following the letter.
Numerals shall be spaced in accordance with Table 1.
3.2.5 Type 5—space letters in accordance with Fig. 5;
spacing shall be equal to the space following the letter.
Numerals shall be spaced in accordance with Table 1 with 1
unit added to each value for shading.

3.3 Spacing Between Words, After Punctuation, or Between
Sentences:
3.3.1 The space between words, after a comma, and after a
period (as after initials) shall be in accordance with Table 1.
3.3.2 The space between sentences shall be in accordance
with Table 1.
3.3.3 The space between a letter and a comma or period (for
any use) shall be 2 units.
3.3.4 The space between lines shall be equal to one half the
height of the tallest letter.

4. Keywords

4.1 block characters; block letters; block numerals; letters;
marine; numerals; plain letters; plain numerals; shading; ship;
ship letters; ship markings; ship numerals

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TABLE 1 Spacing Between Letters and Numerals

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.
<table>
<thead>
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**Spacing Between Words and After Punctuation**

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**Spacing Between Sentences**

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**Key:**
- *—means space for: B.D.E,F,H.I,K,L,M,N,P.R.U 1,3,8 (also used for punctuation and sentence spacing).
- +—means space for: C.G.O.Q.S 0,2,5,6,9.
- Δ—indicates that a portion of a letter enters the area of the next letter.

**Character Spacing:**
Select a character from the vertical column, read across locating the next character, read up to find the correct spacing.

**Example:**
If the letter “K” is followed by the letter “A” the spacing is 1 unit.
If the letter “F” is followed by the letter “H” the spacing is 2 units.

**Punctuation and Sentence Spacing:**
Locate in column of table the last character of word, read across locating (*), drop vertically down to the appropriate row and read spacing.

**Example:**
If the first word was “vessel,” the spacing to the first letter of the next word is 12[1/2]P units.
FIG. 1 Type 1—Plain Letters and Numerals

FIG. 2 Type 2—Block Letters and Numerals

Note—Height: Letters—16 Units
Numerals—16 Units

Note—Height: Letters—12 Units
Numerals—12 Units
FIG. 3  Type 3—Type 2 Characters with Shading

Note—Shading 1 Unit Wide

FIG. 4  Type 4—Block Letters and Numerals

Note—Height: Letters—10 Units
      Numerals—12 Units
FIG. 5 Type 5—Type 4 Characters with Shading

Note—Shading 1 Unit Wide.
Standard Practice for Quality Control Receipt Inspection Procedures for Protective Coatings (Paint), Used in Marine Construction and Shipbuilding

1. Scope

1.1 This practice provides the quality control receipt inspection procedures for protective coatings (paints) procured for end item use on ships and other marine structures. The practice includes methods and procedures for verifying that coating materials received are within the range of physical and chemical characteristics as those originally specified and tested.

1.2 This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints
D 523 Test Method for Specular Gloss
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer
D 1200 Test Method for Viscosity by Ford Viscosity Cup
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
D 1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
D 1309 Test Method for Settling Properties of Traffic Paints During Accelerated Storage
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials
D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates
D 2369 Test Method for Volatile Content of Coatings
D 2671 Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints
D 2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
D 2698 Test Method for Determination of the Pigment Content of Solvent-Reducible Paints by High-Speed Centrifuging
D 2805 Test Method for Hiding Power of Paints by Reflectometry
D 2832 Guide for Determining Volatile and Nonvolatile Content of Paint and Related Coatings
D 3278 Test Methods for Flash Point of Liquids by Setaflsh Closed-Cup Apparatus
D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings

3. Terminology

3.1 Batch—a manufacturing run. The industrial unit or quantity of production made in one complete operation. The volume or mass that constitutes a batch is flexible and varies with the size of the plant and its facilities for converting the raw materials into the finished product.

4. Summary of Practice

4.1 Test requirements for identifying characteristics (physical and chemical) of marine coatings are established. Receipt inspection tests are provided to assure that procured paints do not differ significantly from the paints initially evaluated.
5. Significance and Use

5.1 This practice provides a means of assuring that products supplied during ship construction and maintenance are substantially the same as the materials on which the original selection was based. The selection of a paint for shipboard use frequently involves laboratory and field evaluations of candidate materials as part of the specification process. When a paint is selected, it shall have the same composition and characteristics throughout the delivery period as the materials originally evaluated.

5.1.1 When significant changes in composition or paint characteristics are observed, it is necessary to determine the cause of the change (production error or formulation change) and its impact on coating performance. Actions to take if a formulation change is required are specified in 6.5.

5.2 This practice is not meant to cover all possible chemical or physical tests that may be used to identify a coating. Additional tests may be needed to meet specific user needs.

5.3 This practice does not recommend specific tolerance limits for the tests indicated. Tolerance values need to be agreed upon by the coating supplier, the shipbuilder, and the ship’s owner.

5.4 This practice does not establish critical attributes that must be controlled. These attributes are selected by the shipbuilder and the ship’s owner based on specific needs (for example, colors).

6. Procedures

6.1 At the beginning of each contract, after protective coatings selection, the selected material supplier(s) furnish the values for each property listed in Table 1 for each paint selected. This data shall include accept/reject tolerances. These tolerances shall then be reviewed and approved by the shipbuilder.

NOTE 1—Other properties may be specified by the shipbuilder if deemed important due to the special service requirements of the coatings.

6.2 The shipbuilder may retain a sample of each batch of paint received from the paint supplier (minimum sample size of one pint). This retained sample shall be stored for future reference formula verification.

6.3 Each batch of protective coatings (paint) received under the contract shall, as a minimum, be sampled and tested in accordance with the procedures listed in Table 2.

6.4 The data collected on each batch of material tested in accordance with 6.3 shall then be compared to the base line data established in accordance with 6.1. Any variance not within the approved tolerances shall be cause for rejection of the material. If the material complies with 6.3 but is considered suspect, the additional tests listed in Table 1 shall be performed. Any variance not within the approved tolerances shall also be grounds for rejection.

6.5 Once the material selection has been made against a proprietary formulation, the formulation shall not be changed unless approved by the coating supplier, shipbuilder and owner. If approved, the data furnished in 6.1 shall be updated by the paint material supplier.

### TABLE 1 Initial Baseline Paint Tests

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Property Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 562</td>
<td>Consistency of paints</td>
</tr>
<tr>
<td>D 1200</td>
<td>Viscosity of paints, varnishes, and lacquers</td>
</tr>
<tr>
<td>D 1210</td>
<td>Fineness of dispersion of pigment vehicle systems</td>
</tr>
<tr>
<td>D 1475</td>
<td>Density of paint, varnish, lacquer, and related products</td>
</tr>
<tr>
<td>D 1640</td>
<td>Drying, curing, or film formation of organic coatings</td>
</tr>
<tr>
<td>D 2196</td>
<td>Rheological properties of non-Newtonian materials</td>
</tr>
<tr>
<td>D 2697</td>
<td>Volume nonvolatile matter in clear or pigmented coatings</td>
</tr>
<tr>
<td>D 2832</td>
<td>Nonvolatile content of paint and paint materials</td>
</tr>
</tbody>
</table>

### TABLE 2 Routine Receipt Inspection Tests

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Property Measured</th>
</tr>
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<td>D 2196</td>
<td>Rheological properties of non-Newtonian materials</td>
</tr>
</tbody>
</table>
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the contract or order.

**S1. Quality Assurance**

S1.1 Commercial usage quality assurance testing shall consist of the minimum designated tests of Table 1 and Table 2. Test requirements not covered by these tables shall be agreed upon by the shipbuilder and the shipowner.

S1.2 When specified in the contract or order, Table S1.1 shall be substituted for Table 1 in 6.1 and Table S1.2 shall be substituted for Table 2 in 6.3.

S1.3 Quality assurance for paints procured for use on Navy ships shall include all applicable tests of Table S1.1 and Table S1.2.

S1.4 Both commercial and Navy usage may require tests in addition to those specified in Table 1, Table 2, Table S1.1, and Table S1.2. Typically, these tests will be required for special service conditions. Such test requirements, and the specific test procedures must be specified in the contract or purchase order.

### TABLE S1.1 Initial Baseline Paint Tests

**NOTE**—Test Methods D 562, D 1200, and D 2196 can be used for consistency measurements. Unless otherwise specified, any one of these three test methods may be used.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Property Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 185</td>
<td>Coarse particles in pigments, pastes, and paints</td>
</tr>
<tr>
<td>D 523</td>
<td>Specular gloss</td>
</tr>
<tr>
<td>D 562</td>
<td>Consistency of paints</td>
</tr>
<tr>
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<td>Viscosity of paints, varnishes, and lacquers</td>
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<td>D 1210</td>
<td>Fineness of dispersion of pigment vehicle systems</td>
</tr>
<tr>
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</tr>
<tr>
<td>D 2244</td>
<td>Instrumental evaluation of color</td>
</tr>
<tr>
<td>D 2369</td>
<td>Volatile content of coatings</td>
</tr>
<tr>
<td>D 2621</td>
<td>Infrared identification of vehicle solids</td>
</tr>
<tr>
<td>D 2697</td>
<td>Volume nonvolatile matter in clear or pigmented coatings</td>
</tr>
<tr>
<td>D 2698</td>
<td>Pigment content of solvent-type paints</td>
</tr>
<tr>
<td>D 2805</td>
<td>Hiding power of paints</td>
</tr>
<tr>
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<tr>
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</tr>
</tbody>
</table>
### TABLE S1.2 Routine Receipt Inspection Tests

**NOTE**—Test Methods D 562, D 1200, and D 2196 can be used for consistency measurements. Unless otherwise specified, any one of these test methods may be used.

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Standard Practice for
Inspection of Marine Surface Preparation and Coating Application

This standard is issued under the fixed designation F 941; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is intended to serve as a guide for determining specific inspection requirements for marine surface preparation and coating application during new construction, major retrofit, or routine maintenance contracts.

1.2 It is intended that this practice be used to coordinate inspection activities between ship owner, ship builder, coatings manufacturer and coatings applicator, and that specific requirements be developed before the commencement of surface preparation or coating application, or both.

1.3 This practice does not provide a means of recording required data (for example, film thicknesses, temperatures, relative humidity, etc.), but instead establishes a format for deciding what data must be recorded, when during the preparation/coating process, and by whom.

1.4 This practice does not establish accept/reject criteria for surface preparation or coating inspection, nor does it address methods of repairing deficiencies found. It does, however, provide a means of determining them.

1.5 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D 3276 Guide for Painting Inspectors (Metal Substrates)
D 4940 Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives
F 718 Standard for Shipbuilders and Marine Paints and Coatings Product/Procedure Data Sheet

2.2 SSPC Standards:
SSPC PA 2 Measurement of Film Thickness
SSPC-SP 1 Solvent Cleaning
SSPC-SP 3 Power Tool Cleaning
SSPC-SP 5 White Metal Blast Cleaning
SSPC-SP 6 Commercial Blast Cleaning
SSPC-SP 7 Brush-Off Blast Cleaning
SSPC-SP 10 Near-White Blast Cleaning
SSPC VIS-1 Pictorial Surface Preparation Standards for Painting Steel Surfaces

2.3 JSRA Standard:
JSRA Standard for the Preparation of Steel Surface Prior to Painting

2.4 ISO Standards:
ISO 8501-1:1988 Preparation of Substrates Before Application of Paints and Related Products—Visual Assessment of Surface Cleanliness
ISO 8502-2:1992 Preparation of Substrates Before Applications of Paints and Related Products—Tests for the Assessment of Surface Cleanliness—Laboratory Determination of Chloride on Cleaned Surfaces
ISO 8502-3:1992 Preparation of Substrates Before Applications of Paints and Related Products—Tests for the Assessment of Surface Cleanliness—Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure Sensitive Tape Method)
ISO 8502-6 Preparation of Substrates Before Applications of Paints and Related Products—Tests for the Assessment
of Surface Cleanliness—Field Extraction of Water Soluble Salts (Dr. Bresle Method)
ISO 8502-9 Preparation of Substrates Before Applications of Paints and Related Products—Tests for the Assessment of Surface Cleanliness—Field Evaluation of Water Soluble Salts by Conductimetric Evaluation
ISO 8503-1:1988 Preparation of Substrates Before Application of Paints and Related Products—Surface Roughness Characteristics of Blast-Cleaned Steel Substrates—Comparator Procedure
ISO 8504-1:1992 Preparation of Substrates Before Application of Paints and Related Products—Surface Preparation Methods—General Guidelines
2.5 ASTM Adjuncts:
- Sample Form for Determining Marine Surface Preparation and Coating Application Inspection Practices (F 941)\(^7\)

3. Significance and Use

3.1 This practice may be invoked by any of the parties mentioned in 1.2 and may be included as part of a specification or used to clarify or reinforce an existing specification that does not adequately address inspection. When invoked by the ship owner on the shipbuilder, the shipbuilder is responsible for the coordination effort.

3.2 As surface preparation and coating requirements generally differ from ship area to ship area, this practice shall be applied separately to those areas of similar requirements.

3.3 The contents of this practice shall be addressed (for each applicable ship area) at a prestartup meeting attended by the parties mentioned in 1.2.

4. Procedures

4.1 At the beginning of each new contract, after final protective coatings selection, but well before the start of any surface preparation or coating application, a meeting shall be held between those parties mentioned in 1.2. The Sample Form for Determining Marine Surface Preparation and Coating Application Inspection Practices\(^7\) shall be completed (for each separate ship area) by the responsible party prior to and each item discussed and agreed upon during the meeting. The selected coating supplier(s) shall make available at this time specific product data sheets in accordance with Standard F 718 harmonizing with the design intent of the application for each coating specified.

4.2 After completion of the sample form,\(^7\) and required documentation has been submitted by the coatings supplier(s), signatures of applicable parties shall be obtained and dated.

4.3 A means of collecting and recording the information required by the sample form\(^7\) shall be developed (see 5.1.6.4).

5. Report

5.1 The following paragraphs coincide with the individual sections of the sample form\(^7\) to aid in their proper completion. Guide D 3276 shall be consulted for additional guidance on general surface preparation and coating inspection practices.

5.1.1 Contract—Indicate name of vessel, present owner/agent, and type of vessel (for example, roll-on/roll-off, tanker, etc.).

5.1.2 Category—Indicate whether contract is a new construction, major retrofit, or routine maintenance contract.

5.1.3 Ship Area(s) Concerned—Indicate the ship area(s) (for example, underwater hull, ballast tanks, etc.) that are being addressed in the inspection practice. Where appropriate, frame numbers or ship levels, or both, shall be included.

5.1.4 Surface Preparation Requirements:

5.1.4.1 Surface Preparation, Initial—Indicate the standard(s) that will be used to govern the initial surface preparation process, for the particular ship area(s) under consideration. Both written and visual standards shall be used (ISO, JSRA, NACE, or SSPC as appropriate).\(^8\)

5.1.4.2 Surface Preparation, Touch-Up—Indicate the surface preparation that will be used for repair of small areas of coating damage or areas, or both, left free of coatings (for example, erection butts) during construction.

5.1.4.3 Abrasive—As a minimum, indicate the type and size of the abrasive that will be used to perform the surface preparation process. Any other data (minimum hardness, moisture content, salt content as per Test Method D 4940, etc.) considered pertinent shall also be considered.

5.1.4.4 Surface Profile—Indicate any requirements for surface profile (after preparation), and the method that will be used to perform the measurements.

5.1.4.5 Surface Imperfections—Specific requirements for repair or removal of surface imperfections, or both, if not adequately addressed or defined in the applicable surface preparation standard, shall be included in this section. These imperfections include weld spatter, weld porosities, laminations, sharp edges, and pits.

\(^{7}\) A Sample Form for Determining Marine Surface Preparation and Coating Application Inspection Practices is available at a nominal cost from ASTM Headquarters. Order ADHJ0941.

\(^{8}\) SNAME Bulletin 4-9, available from The Society of Naval Architects and Marine Engineers, 601 Pavonia Ave., Jersey City, NJ 07306, may also be used as an additional reference. This document shall be used as a guide only and is not to be used as a standard.
5.1.4.6 Cleaning Between Coats—Indicate allowable methods for removal of contaminants from the surface of the primer or intermediate coats before overcoating.

5.1.5 Coating Requirements:

5.1.5.1 Specification, Initial—Indicate the complete coating system specified to be applied to the ship area(s) under consideration. Include the manufacturer’s name, product designation or specification number, required color, and required dry film thickness per coat.

5.1.5.2 Specification, Touch-Up—Indicate the coating system (if different from the initial system) that will be used to repair areas of coating damage or areas left uncoated, or both, during construction. Include the manufacturer’s name, product designation or specification number, required color, and dry film thickness per coat.

5.1.5.3 Application Parameters—Standard F 718 product data sheet shall be completed by the coatings manufacturer for each product specified; these data sheets shall be used to establish specific parameters such as minimum/maximum application temperatures and recoat times, mixing procedures, measurement of wet/dry film thickness, etc. Completed data sheets shall be attached to the applicable inspection practice before obtaining approval signatures. The manufacturers’ Material Safety Data Sheets shall be obtained for each product and similarly attached.

5.1.5.4 Stripe Coats—Indicate where stripe coats are required, when applied, what coating should be used, and the allowable method(s) of application.

5.1.6 Inspections:

5.1.6.1 Timing and Frequency—Indicate when inspections will occur during the surface preparation and coating application processes, and their frequency (per unit surface area).

5.1.6.2 Responsibilities—Indicate all persons (name, employer, position, telephone number) that must be present at the time of inspection, and a procedure to follow in the event of their absence or delay.

5.1.6.3 Notification Procedure—Develop a procedure which establishes a specific method for notifying all responsible parties that a ship area is ready for inspection.

5.1.6.4 Record Keeping—Indicate what will be recorded at each inspection, who will accomplish the recording, how the information will be recorded, and to whom copies should be sent. A form shall be developed to aid in this recording process. Space shall be provided for approval or disapproval of the surface preparation or coating application, for noting exceptions found and correction of discrepancies, and for final “sign off” of the completed ship area under consideration.

5.1.7 Sequencing of Work—Indicate the general order of accomplishment of the specified surface preparation and coating work, and any additional information that might aid in assuring a smooth flow of this work.

5.1.8 Approvals—Signatures shall be obtained from all responsible parties after a thorough review of the completed inspection practice (see Sample Form for Determining Marine Surface Preparation and Coating Application Inspection Practices and all attached documentation.

6. Keywords

6.1 coating application; inspection requirements; marine surface preparation

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Standard Specification for
Bell, Cast, Sound Signalling1

This standard is issued under the fixed designation F 956; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers cast sound-signalling bells, together with bulkhead mounting plates for the smaller bells, for use on ships, boats, and other marine craft, for compliance with the rules in the convention on the International Regulations for Preventing Collisions at Sea (commonly called Colregs).2 See Appendix X1.

1.2 Bells and bulkhead mounting plate shall be sized as indicated in Section 4 (see Appendix X2).

1.3 For consistency with International Regulations, all measurements are in SI units.

2. Referenced Documents

2.1 ASTM Standards:
B 584 Specification for Copper Alloy Sand Castings for General Applications3

2.2 Other Documents:
CFR 33 Part 81–72 Implementing Rules2
CFR 33 Part 86, Subpart B, Bell or Gong2

3. Terminology

3.1 Definitions:
3.1.1 bell, n—a hollow metal instrument that rings when struck.
3.1.2 cast, v—to form by molding in a hollow form for shaping a liquid or plastic substance.
3.1.3 clapper, n—the hammer like object inside a bell.

4. Classification

4.1 Bells shall be furnished in the following sizes, based on bellmouth diameter in millimetres (see Appendix X2):
4.1.1 150 mm,
4.1.2 200 mm (2.2 kg),
4.1.3 200 mm (4.5 kg),
4.1.4 250 mm,
4.1.5 300 mm,
4.1.6 360 mm,
4.1.7 400 mm, and
4.1.8 550 mm.

4.2 Bulkhead mounting plates shall be furnished for the following bell sizes:
4.2.1 150 mm, and
4.2.2 200 mm.

5. Ordering Information

5.1 Orders for materials under this specification shall include the following information:
5.1.1 ASTM designation and year of issue.
5.1.2 Number of bells.
5.1.3 Size of bell(s) (see 4.1).
5.1.4 Additional bulkhead mounting plates (see 4.2 and 6.2.2).
5.1.5 Inscription required (see 12.1).
5.1.6 Packaging, if other than commercial (see Section 13).

6. Materials and Manufacture

6.1 Material:
6.1.1 Bell bodies, clappers, and other cast fittings and parts shall be copper alloy conforming to Specification B 584, UNS C 87200.
6.1.2 Fittings such as bolts, nuts, washers, pins, and supporting lugs shall be of copper alloy compatible with the bell castings.

6.2 Manufacture:
6.2.1 Construction shall be in accordance with Fig. 1, Fig. 2, and Fig. 3.
6.2.2 For Fig. 1 and Fig. 2, one bulkhead mounting plate shall be furnished with each bell, however, additional mounting plates may be ordered.
6.2.3 For all bells, two extra supporting nuts, washers, and acorn nuts (where used) shall be furnished.

7. Acoustic Requirements

7.1 Bells shall have full, clear, round, and farreaching tones. The sound pressure level shall not be less than 110 dB at a distance of 1 m from it.
8. Dimensions, Mass, and Permissible Variations

8.1 Dimensions and mass of bells, together with tolerances, shall conform to Fig. 1, Fig. 2, and Fig. 3.

9. Workmanship, Finish, and Appearance

9.1 Bells shall be free of cracks, burrs, sharp cutting edges, adhering sand, and other defects and blemishes affecting their life, appearance, and serviceability.

9.2 Bell exteriors and the lower part of the interior, from the bellmouth to 10 mm above the line where the clapper strikes the bell, shall have a smooth polished finish. The “visible” part of the clapper shall have a similar finish.

10. Sampling

10.1 For orders for 1 or 2 bells of the same size, each bell shall be inspected and tested.

10.2 For orders for 3 to 10 bells of the same size, 2 bells shall be selected at random. If any one of them fails to meet the requirements, then all bells in the order shall be inspected and tested.

10.3 For orders for more than 10 bells of the same size, they shall be separated into groups of 10 (or fraction thereof) for sampling purposes.

11. Inspection and Testing

11.1 Responsibility—Unless otherwise specified in the order, the manufacturer is responsible for the performance of all inspection requirements specified herein. The manufacturer may utilize his own facilities or any commercial facilities acceptable to the purchaser. The purchaser reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure that supplies conform to the prescribed requirements. Nonconforming bells shall not be offered for delivery.

11.2 Inspections:

11.2.1 The dimensions of the bell and appurtenances shall be checked to ensure that they are within the specified tolerances.

11.2.2 The bell, without bracket or mounting plate (for 150 mm and 200 mm light), and clapper shall be weighed separately to ensure that the mass is within the specified tolerance.

11.2.3 For the 150 and 200 light sizes, the brackets shall be engaged and disengaged from each of the mounting plates to ensure portability.

11.3 Acoustic Tests—Acoustic tests shall be conducted only for the 200 mm heavy and larger bells to check the requirements of 7.1. Each bell tested shall be supported by the yoke or eyebolt with the clapper in place. The bell shall be rung by striking the bell with the clapper, activated by a lanyard.

11.3.1 The sound, produced in accordance with Appendix X1.1, shall be measured in a space with no large sound reflecting surfaces (except the floor) that are within 10 m. The sound shall be measured using a commercial sound level meter.
located at a distance of 1 m and at a height above the floor equal to that of the striking point.

12. Product Marking

12.1 Owner’s inscription shall be as specified. It shall be applied either by being cast in relief (raised) or by engraving. Size and location shall be the same as U.S. shown in Fig. 1, Fig. 2, and Fig. 3.

12.1.1 For bells intended for use on ships, boats, and other watercraft of the U.S. Army and Navy and other government agencies, the inscription shall be U.S.; size and location shall be as shown in Fig. 1, Fig. 2, and Fig. 3.

12.2 The letters ASTM and this specification number shall be engraved on the shank of each bell in figures at least 6 mm high.

12.3 The manufacturer may engrave his brand name or logo on the shank of the bell.

13. Packaging and Package Marking

13.1 No preservation is required.

13.2 Unless otherwise specified, packing shall conform to manufacturer’s normal commercial practice, and in such a manner that will ensure acceptance by common carrier and afford protection against physical and mechanical damage.
during shipment. Shipping containers shall conform to carrier regulations as applicable to the mode of transportation.

13.3 For procurements by the U.S. Department of Defense for long-term storage or overseas shipment, the requirements of Annex A1 apply. In such case the required level of packing shall be specified.

14. Keywords

14.1 bell; bell casting; clapper; sound pressure level; sound signalling

ANNEX

(Mandatory Information)

A1. PACKING FOR DoD PROCUREMENTS

A1.1 Applicable Documents for This Annex Only:
A1.1.1 Federal Specifications:
PPP-B-576 Box, Wood, Cleated, Veneer, Paper Overlaid
PPP-B-585 Boxes, Wood, Wirebound
PPP-B-591 Boxes, Fiberboard, Wood-Cleated
PPP-B-601 Boxes, Wood, Cleated-Plywood
PPP-B-621 Boxes, Wood, Nailed and Lock Corner
PPP-B-636 Box, Fiberboard
PPP-B-640 Boxes, Fiberboard, Corrugated, Triple, Wall
A1.1.2 Military Standard:
MIL-STD-129 Marking for Shipment and Storage
A1.1.3 Other Documents:
Official Classification Committee Rules
Uniform Freight Classification Rules

A1.2 Preservation—None required.

A1.3 Packing—The bells shall be cushioned, blocked, or braced within the containers in a manner to prohibit movement and the clappers shall be secured or cushioned to prevent knocking. Unless otherwise specified in the order, one bell shall be packed per container. When more than one bell is required to be packed in each container, the gross mass of the wood or wood-cleated boxes shall not exceed approximately 100 kg.

A1.3.1 Level A

Bells shall be packed in containers conforming to any one of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Class 2</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 3</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Weather-resistant</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Domestic type</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 1</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>Weather-resistant</td>
</tr>
<tr>
<td>PPP-B-640</td>
<td>Class 2</td>
</tr>
</tbody>
</table>

A1.3.1.1 Boxes shall be closed and banded in accordance with the applicable box specification or appendix thereto.

A1.3.2 Level B

Bells shall be packed in boxes conforming to any of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Class 2</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 2 use</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Weather-resistant</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Domestic type</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 1</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>Weather-resistant</td>
</tr>
<tr>
<td>PPP-B-640</td>
<td>Class 2</td>
</tr>
</tbody>
</table>

A1.3.2.1 Box closure and banding or reinforcement shall be as specified in the box specification or appendix thereto with Method V closure applicable to PPP-B-636 boxes. The gross mass of wood or wood-cleated boxes shall not exceed 100 kg.

A1.3.3 Level C

Bells shall be packed as specified for Level B except that the containers may be of the non-weather-resistant type or grade and Method I closure shall apply for PPP-B-636 boxes.

A1.4 Marking—In addition to any special marking required by the order, shipments shall be marked in accordance with MIL-STD-129.
X1. EXCERPTS FROM U.S. COAST GUARD RULES

X1.1 For general information, the following is quoted from U.S. Coast Guard Commandant Instruction M 16672.2: Navigation Rules, International-Inland, Division II, Part D, Rule 33—Equipment for Sound Signals.

“(A) A vessel of 12 meters or more in length shall be provided with a whistle and a bell and a vessel of 100 meters more in length, shall, in addition, be provided with a gong, the tone and sound of which cannot be confused with that of the bell. The whistle, bell and gong shall comply with the specifications in Annex III to these regulations. The bell or gong, or both, may be replaced by other equipment having the same respective sound characteristics, provided that manual sounding of the prescribed signals shall always be possible.

(B) A vessel of less than 12 meters in length shall not be obliged to carry the sound signalling appliances prescribed in Paragraph (A) of this rule but if she does not, she shall be provided with some other means of making an efficient sound signal.

In Addition:

Division II, Part E, Annex III—Technical Detail of Sound Signalling Appliances, and 33 CFR Part 86, Subpart B:

2. Bell or Gong:

(A) Intensity of Signal—A bell or gong, or other device having similar sound characteristics shall produce a sound pressure level of not less than 110 dB at a distance of 1 meter from it.

(B) Construction—Bells and gongs shall be made of corrosion-resistant material and designed to give a clear tone. The diameter of the mouth of the bell shall be not less than 300 mm for vessels of 20 meters or more in length, and shall be not less than 200 mm for vessels of 12 meters or more but of less than 20 meters in length. Where practicable, a power-driven bell striker is recommended to ensure constant force but manual operation shall be possible. The mass of the striker shall be not less than 3 % of the mass of the bell.

3. Approval—The construction of sound signal appliances, their performance and their installation on board the vessel shall be to the satisfaction of the appropriate authority of the state whose flag the vessel is entitled to fly.

Division II, Part E, Subpart B—Bell or Gong, Inland Rules:

86.21 Intensity of Signal—A bell or gong, or other device having similar sound characteristics shall produce a sound pressure level of not less than 110 dB at 1 meter.

86.23 Construction—Bells and gongs shall be made of corrosion-resistant material and designed to give a clear tone. The diameter of the mouth of the bell shall be not less than 300 mm for vessels of more than 20 meters in length, and shall be not less than 200 mm for vessels of 12 to 20 meters in length. The mass of the striker shall be not less than 3 % of the mass of the bell. The striker shall be capable of manual operation.

Note X1.1—When practicable, a power-driven bell striker is recommended to ensure constant force.”

X2. GUIDELINES FOR USE OF BELLS

X2.1 The ship’s bells covered by this specification are intended for use on the following:

X2.1.1 Bell Type:

X2.1.1.1 150 mm and 200 mm (2.2 kg)
Small craft and boats less than 12 m in length, quarter-deck bells and fire bells.

X2.1.1.2 200 mm (4.5 kg)—Boats 12 m to 20 m in length and ships watch and fire bell.

X2.1.1.3 250 mm—Vessels 12 m to 20 m in length, submarines less than 100 m in length.

X2.1.1.4 300 mm—Vessels 20 m to 50 m in length, submarines 100 m and over in length.

X2.1.1.5 360 mm—Vessels 50 m to 75 m in length.

X2.1.1.6 400 mm—Vessels 75 m to 150 m in length.

X2.1.1.7 550 mm—Vessels over 150 m in length.
1. Scope

1.1 This specification covers gongs for use on ships 100 m or more in length, as required by International Regulations (see Appendix X1).

1.2 For consistency with International Regulations, all measurements are in SI units.

2. Referenced Documents

2.1 ASTM Standards:
- A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
- A 276 Specification for Stainless Steel Bars and Shapes
- D 3951 Practice for Commercial Packaging

2.2 American Welding Society Standard:
- AWS D1.1 Structural Welding Code

2.3 Federal Specifications:
- PPP-B-576 Box, Wood, Cleated, Veneer, Paper Overlay
- PPP-B-585 Boxes, Wood, Wirebound
- PPP-B-591 Boxes, Fiberboard, Wood-cleated
- PPP-B-601 Boxes, Wood, Cleated Plywood
- PPP-B-621 Boxes, Wood, Nailed and Lock Corner

2.4 Military Standard:
- MIL-STD-129 Marking for Shipment and Storage

3. Ordering Information

3.1 Orders for gongs under this specification shall include the following information:

3.1.1 ASTM designation and year of issue.

3.1.2 Number of gongs.

3.1.3 Packaging and marking, if other than commercial.

4. Materials and Manufacture

4.1 Materials:

4.1.1 The gong cylinder, brackets, clapper rod, “U” bracket, washers, and clapper support pin shall be of stainless steel, in accordance with Specification A 167, UNS number S31600.

4.1.2 The clapper mass shall be of cast alloy steel in accordance with Specification A 276, UNS S31600.

4.1.3 The support bolt, nut, flat washer, and cotter pins shall be of stainless steel compatible with the other materials.

4.2 Welding:

4.2.1 Welding shall be of the type and sizes shown in Fig. 1 and Fig. 2, and in accordance with Standard AWS D1.1.

4.3 Manufacture:

4.3.1 Fig. 1 shows the general arrangement of the assembled gong, as well as details of the gong cylinder. Fig. 2 shows details of the brackets, clapper, and miscellaneous fittings.

4.3.2 The gong cylinder may be made from two pieces welded together, instead of one piece. Two piece construction shall be annealed to remove residual stresses.

4.3.3 Sharp corners and edges of the cylinder shall be broken.

4.3.4 The two brackets shall be welded together before being welded to the cylinder. The flanged ends of the brackets may be left straight and not shaped to the cylinder.

4.3.5 The clapper mass shall be welded to the clapper rod before forming the second eye.

4.4 Extra Parts:

4.4.1 Two extra supporting nuts and flat washers shall be furnished with each gong.

5. Acoustic Requirements

5.1 The sound characteristics shall produce a sound pressure level of not less than 110 dB at a distance of 1 m.

6. Dimensions and Tolerances

6.1 Dimensions shall conform to Fig. 1 and Fig. 2.

6.2 Tolerances shall be as follows:

6.2.1 Up to 10 mm: ± 1 mm.

6.2.2 10 mm to 50 mm: ± 2 mm.

6.2.3 Over 50 mm: ± 3 mm.
7. Workmanship, Finish, and Appearance

7.1 Gongs shall be free from cracks, burrs, sharp cutting edges, and other defects affecting their life, appearance, and serviceability.

8. Sampling

8.1 For orders of 1 or 2 gongs, each gong shall be inspected and tested.
8.2 For orders of 3 to 10 gongs, 2 gongs shall be selected at random. If any one of them fails to meet requirements, then all gongs in the order shall be inspected and tested.

8.3 For orders of more than 10 gongs, they shall be separated into groups of 10 (or fraction thereof) for sampling purposes.

9. **Inspection and Testing**

9.1 **Responsibility**—Unless otherwise specified in the purchase order, the manufacturer shall be responsible for the performance of all inspection and testing specified herein. The manufacturer may utilize his own facilities or any commercial facility acceptable to the purchaser. The purchaser reserves the right to perform any of the inspections and tests set forth where such are deemed necessary to ensure that supplies conform to prescribed requirements. Nonconforming gongs shall not be offered for delivery.

9.2 **Inspection**—The dimensions of the gong and its components shall be checked to ensure that they are within specified tolerances.

9.3 **Acoustic Test**—Each gong tested shall be supported as shown in Fig. 1 with the clapper in place. The gong shall be rung by striking the cylinder with the clapper, activated by a lanyard. The sound, produced in accordance with Appendix X1, shall be measured in a space with no large sound reflecting surfaces (except the floor) that are within 10 m. The sound shall
be measured using a commercial sound level meter located at a distance of 1 m and at a height above the floor equal to that of the striking point.

10. Product Marking

10.1 The letters “ASTM” and this specification number shall be engraved on the gong cylinder in figures at least 6 mm high.

10.2 The manufacturer may engrave his brand name or logo on the inside of the gong cylinder.

11. Packaging and Package Marking

11.1 No preservation is required.

11.2 Unless otherwise specified, packaging and marking shall conform to Practice D 3951 and shall, when specified, include bar code marking.

11.3 For government procurements for long-term storage or overseas shipment, the requirements of Annex A1 apply. In such case the required level of packaging shall be specified.

12. Supersession

12.1 This specification is intended to supersede Bureau of Ships drawing S2408-F-921899. The cancellation of Bureau of Ships S2408-F-921899 drawing and adoption of this specification can only be effected by the Navy.

Note 1—The Bureau of Ships was one of the predecessors of the Naval Ship/Sea Systems Command.

13. Keywords

13.1 clapper; gong; gong cylinder; signaling; sound signaling

ANNEX

(Mandatory Information)

A1. PACKING FOR DOD PROCUREMENTS

A1.1 Applicable documents for this annex only.

A1.1.1 Federal Specifications—PPP-B-576, PPP-B-585, PPP-B-591, PPP-B-601, and PPP-B-621.


A1.2 Preservation—None required.

A1.3 Packing—The gong shall be cushioned, blocked, or braced within the container in a manner to prohibit movement, and the clappers shall be secured or cushioned to prevent knocking. Unless otherwise specified in the purchase order, one gong shall be packed per container. When more than one gong is required to be packed in each container, the gross mass of the wood or wood-cleated boxes shall not exceed approximately 100 kg (220 lbs).

A1.3.1 Level A—Gongs shall be packed in containers conforming to any of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-585</td>
<td>Class 3</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 2</td>
</tr>
</tbody>
</table>

A1.3.1.1 Boxes shall be closed and banded in accordance with the applicable box specification.

A1.3.2 Level B—Gongs shall be packed in boxes conforming to any of the following specifications at the option of the manufacturer.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Class 2</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 1 or 2</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Weather–resistant</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 1</td>
</tr>
</tbody>
</table>

A1.3.2.1 Box closures shall be as specified in the applicable box specification.

A1.3.3 Level C—Gongs shall be packed and have container closure as specified for Level B, except that containers may be of the domestic type or class.

A1.3.4 Commercial packing shall conform to 11.2.

A1.4 Marking—In addition to any special marking required by the order, shipments shall be marked in accordance with MIL-STD-129 or Practice D 3951 as applicable and when specified shall include bar code markings.
X.1. EXCERPTS FROM U. S. COAST GUARD RULES

X.1.1 For general information, the following is quoted from U. S. Coast Guard Commandant Instruction M16672.2A: Navigation Rules, International-Inland.

X.1.1.1 Division II, Part D, Rule 33—Equipment for Sound Signals:

(b) Construction—Bells and gongs shall be made of corrosion-resistant material and designed to give a clear tone. The diameter of the mouth of the bell shall be not less than 300 mm for vessels of 20 m or more in length, and shall be not less than 200 mm for vessels of 12 m or more but of less than 20 m in length. Where practicable, a power-driven bell striker is recommended to ensure constant force but manual operation shall be possible. The mass of the striker shall be not less than 3 % of the mass of the bell.

X.1.1.2 Division II, Part E, Annex III—Technical Details of Sound Signal Appliances: International Rules:

X.1.1.2.2 Bell or Gong:

(a) Intensity of Signal—A bell or gong, or other device having similar sound characteristics shall produce a sound pressure level of not less than 110 dB at 1 m.

(b) Construction—Bells and gongs shall be made of corrosion-resistant material and designed to give a clear tone. The diameter of the mouth of the bell shall be not less than 300 mm for vessels of 20 m or more in length, and shall be not less than 200 mm for vessels of 12 m or more but of less than 20 m in length. Where practicable, a power-driven bell striker is recommended to ensure constant force but manual operation shall be possible. The mass of the striker shall be not less than 3 % of the mass of the bell.

X.1.1.3 Division II, Part E, Subpart B—Bell or Gong—Inland Rules:

X.1.1.3.1 Intensity of Signal—A bell or gong, or other device having similar sound characteristics shall produce a sound pressure level of not less than 110 dB at 1 m.

X.1.1.3.2 Construction—Bells and gongs shall be made of corrosion-resistant material and designed to give a clear tone. The diameter of the mouth of the bell shall be not less than 300 mm for vessels of more than 20 m in length, and shall be not less than 200 mm for vessels of 12 to 20 m in length. The mass of the striker shall be not less than 3 % of the mass of the bell. The striker shall be capable of manual operation.

NOTE X.1.1—When practicable, a power-driven bell striker is recommended to ensure constant force.

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Standard Specification for
Panama Canal Pilot Platform

This standard is issued under the fixed designation F 985; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides design and construction details for Panama Canal pilot platforms.

1.2 Platforms shall be placed aboard the vessel in accordance with the requirements of the Panama Canal Commission and Title 35 of the Code of Federal Regulations.

1.3 The values stated in metric units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:
   B 221 Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes
2.2 Federal Standard:
   Code of Federal Regulations, Title 35 Panama Canal Regulations (Parts 1 through 299)

3. Ordering Information

3.1 Pilot platforms shall be ordered by this ASTM designation and year of issue.

3.2 Paint finish (if other than standard).

4. Materials and Methods

4.1 Platforms shall be welded-aluminum construction in accordance with Specification B 221, Alloy 5086.

4.2 Decking shall be serrated-aluminum grating.

4.3 Canopy shall be of vinyl-nylon construction with sewn seams and metallic grommets.

4.4 Canopy tie-downs shall be 1/8-in. (DN 4-mm) nylon line.

4.5 Paint finish, if required, shall be in accordance with customer specifications.

5. Dimensions, Weight, and Permissible Variations

5.1 Dimensions as indicated in Figs. 1-7.

5.2 The approximate unit weight is 1250 N.

5.3 The construction tolerance is 4 mm, except bolt hole location 1 mm.

6. Workmanship, Finish, and Appearance

6.1 Shelters shall be free of weld splatter, sharp edges, and burrs injurious to personnel.

7. Keywords

7.1 Panama Canal; pilot platform
FIG. 1 Pilot Platform
FIG. 5 Floor Details

SECTION "C-C"

SECTION "B-B"

SECTION "A-A"

FIG. 5 Floor Details
FIG. 6 Section Connecting Pins
FIG. 7 Ship Attachment

DETAIL 'C'

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

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Standard Specification for Suction Strainer Boxes

This standard is issued under the fixed designation F 986; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, materials, and construction of strainer boxes for use in ships’ bilges and other such tank locations that require trash protection for suction pipes and pumps.

1.2 This specification covers pipe sizes from NPS 1½ through NPS 16 (see Note 1).

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this specification for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Carbon Structural Steel
A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
F 594 Specification for Stainless Steel Nuts
F 708 Practice for Design and Installation of Rigid Pipe Hangers

2.2 American Welding Society Standard:

AWS D1.3 Structural Welding Code—Sheet Steel

3. Classification

3.1 This specification covers two types of strainer boxes.

3.1.1 Type 1—Strainer boxes with pipe clamp centered on the top of the strainer box (see Fig. 1).

3.1.2 Type 2—Strainer boxes with the pipe clamp off center in the top of the strainer box (see Fig. 2).

4. Ordering Information

4.1 Ordering information required is as follows.

4.1.1 ASTM specification and year of issue.

4.1.2 Type.

4.1.3 Size (suction pipe NPS).

4.1.4 Dimensions G and H (Type 2 only).

4.1.5 Number of each type and size.

5. Materials and Manufacture

5.1 For information on materials, see Table 1.

5.2 Welding shall be in accordance with AWS D1.3.

5.3 Perforated sheet metal shall have 3/8-in. diameter holes on staggered ½-in. centers, 51% open area.

6. Dimensions and Tolerances

6.1 Tolerance—± 1/16 in.

6.2 Strainer Box Dimensions:

6.2.1 Type 1—See Table 2.

6.2.2 Type 2—See Table 3.

7. Workmanship, Finish, and Appearance

7.1 Strainer boxes shall be hot galvanized in accordance with Specification A 123/A 123M after fabrication. The galvanizing shall be a minimum of 2 mils thick.

7.2 Strainer boxes shall be free of defects, burrs, and sharp edges.

8. Installation

8.1 Strainer boxes are normally installed on suction pipes in ballast and bilge spaces.

8.2 Minimum suction pipe or tank bottom clearances are indicated in Column “F” in Table 2 and Table 3. Dimension callout is based on ½ × the tailpipe nominal pipe size.

8.3 Tank structure and sloping bottom structure may obscure the above clearance down to the limit of the resulting periphery clear area, being 1.5 × the inside diameter of the tailpipe. Structure outside the limit of ½ the pipe NPS need not be considered as obstructing flow.
NOTE 1—Tab location to suit perforated holes.

FIG. 1 Type 1—Elevation Strainer Box
FIG. 2 Type 2—Elevation Rectangular Strainer

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Side—Sheet metal, 11 gage, perforated 3/8-in. diameter holes staggered on 1/2-in. centers, carbon steel, Specification A 36/A 36M.</td>
</tr>
<tr>
<td>2</td>
<td>Top—Sheet metal, 11 gage, perforated 3/8-in. diameter holes staggered on 1/2-in. centers, carbon steel, Specification A 36/A 36M.</td>
</tr>
<tr>
<td>3</td>
<td>Tab—Flatbar, 1/4 in. thick by 1 in. wide by 2 in. long, carbon steel, Specification A 36/A 36M or ABS Grade A.</td>
</tr>
<tr>
<td>4</td>
<td>Screw—Tapping, plain hexagon washer head 1/4 nominal size by 3/4 in. long, Type 316 stainless steel, Specification F 593.</td>
</tr>
<tr>
<td>5</td>
<td>Clamp—Split cap, Practice F 708 Fig. 1a, without standoff.</td>
</tr>
<tr>
<td>6</td>
<td>Bolt—Hexagon head, stainless steel, Type 316 Specification F 593. Size in accordance with Practice F 708.</td>
</tr>
<tr>
<td>7</td>
<td>Nut—Hexagon heavy, stainless steel, Type 316 Specification F 594. Size in accordance with Practice F 708.</td>
</tr>
</tbody>
</table>
### TABLE 2 Type 1 Strainer Dimensions

<table>
<thead>
<tr>
<th>Suction Pipe NPS</th>
<th>Strainer Side Width, in.</th>
<th>Strainer Length, in.</th>
<th>Strainer Height, in.</th>
<th>Hole Diameter, in.</th>
<th>Tab Location, in.</th>
<th>Pipe Clearance, in.</th>
<th>Weight, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1½</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>1½</td>
<td>3</td>
<td>3/4</td>
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<tr>
<td>14</td>
<td>42</td>
<td>42</td>
<td>14</td>
<td>14</td>
<td>4 and 10</td>
<td>7</td>
<td>106.2</td>
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<tr>
<td>16</td>
<td>48</td>
<td>48</td>
<td>16</td>
<td>16</td>
<td>5 and 11</td>
<td>8</td>
<td>134.8</td>
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*See 8.2 and 8.3 of this specification.

### TABLE 3 Type 2 Strainer Dimensions

<table>
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<td>1½</td>
<td>3</td>
<td>3/4</td>
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<td>2½</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3½</td>
<td>6½</td>
<td>25</td>
<td>6</td>
<td>3½</td>
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<td>3½</td>
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</tr>
<tr>
<td>3</td>
<td>4½</td>
<td>7½</td>
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<td>6</td>
<td>3½</td>
<td>3</td>
<td>1½</td>
<td>3½</td>
<td>3½</td>
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<td>5½</td>
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<td>4½</td>
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<td></td>
</tr>
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<td>12</td>
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</tr>
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<td>99</td>
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<td>7½</td>
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<td>5 and 11</td>
<td>8</td>
<td>8½</td>
<td>11½</td>
<td></td>
</tr>
</tbody>
</table>

*A Minimum dimensions A and B are independent of one another and relate only to required clearances for the clamp assembly and suction requirements. The total minimum perimeter for the box is shown in the undesignated fourth column.

*B See 8.2 and 8.3 of this specification.
Standard Specification for Portable Intermediate Flush Deck Stanchion

This standard is issued under the fixed designation F 987; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, construction, and installation of intermediate portable flush deck stanchions. Intermediate stanchion is defined as any stanchion that is not an end or corner stanchion.

1.2 Stanchions shall be used on interior and exterior decks, to provide temporary protection to minimize the danger of personnel falling overboard or to a lower level in the ship in areas where the installation of a fixed system would interfere with vessel operations.

1.3 Stanchions may be used with ¾-in. (9.5-mm) galvanized close link chain or wire rope lifelines ¾-in. (14-mm) top course, ¼-in. (11-mm) lower courses.

1.4 This specification covers only the stanchions and does not cover requirements for the chain or wire rope lines to be supported by the stanchion.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
F 783 Specification for Staple, Handgrab, Handle, and Stirrup Rung

2.2 ANSI/ASME Standards:

B 16.11 Forged Steel Fittings, Socket-Welding, and Threaded
B 16.15 Cast Bronze Threaded Fittings

2.3 ANSI/AWS Standard:

D 1.1 Structure Welding Code

2.4 Code of Federal Regulations:

Title 46 Shipping, Parts 70 to 89, Subpart 72.40

3. Classification

3.1 Portable flush deck stanchions shall be available in two types:

3.1.1 Type I—Two-course portable flush deck stanchions (see Fig. 1).

3.1.2 Type II—Three-course portable flush deck stanchions (see Fig. 2).

4. Ordering Information

4.1 Orders for portable flush deck stanchions under this specification shall include the following information:

4.1.1 ASTM designation and year of issue (that is, F 987 – 04).

4.1.2 Type.

4.1.3 Quantity.

4.1.4 If socket plug stowage coupling is required.

4.2 Lifelines shall be ordered separately.

5. Materials and Manufacture

5.1 Materials:

5.1.1 Pipe for stanchion shall be in accordance with Specification A 106, Grade A or B, NPS 1½ , Schedule 80, carbon steel.

5.1.2 Staple shall be in accordance with Specification F 783, Table 1, Type II.

5.1.3 Socket shall be in accordance with Specification A 182/A 182M, ANSI B 16.11, NPS 1½ , 3000 lb, Type 316L, stainless steel (1½-6 UNC-2B).
5.1.4 Socket plug shall be in accordance with ANSI B 16.15, NPS 1½, Bronze-Threaded Class 250, countersunk square head (1½-6 UNC-2B).

5.2 Manufacture:

5.2.1 Welding shall be as shown on Figs. 1-3 and shall be in accordance with ANSI/AWS D1.1.
5.2.2 Stanchion assembly, excluding socket and socket plug, shall be hot-galvanized in accordance with Specification A 123/A 123M.

6. Other Requirements

6.1 Stanchions shall be installed in accordance with contact requirements or as specified below:

6.1.1 Portable flush deck stanchions shall not be used on inclined ladders.

6.1.2 Type I Stanchions—Required on bridges, platforms, walkways, and elsewhere as needed in accordance with 46 CFR (see 3.1).

6.1.3 Type II Stanchions—Required along the exposed peripheries of freeboards, weather decks and superstructure decks in accordance with 46 CFR (see 3.1).

7. Installation

7.1 The intended installation is to follow these general guidelines:

7.1.1 There shall be a maximum clearance of 4 in. (101.6 mm) between stanchion centerline and other structure.

7.1.2 Sockets shall be installed and aligned so that stanchions are perpendicular to the ship’s baseline.

7.1.3 Stanchions shall be installed with 10 ft (3050 mm) maximum between centers; 6 ft (1830 mm) minimum.

7.1.4 Socket plugs shall be provided for installation in deck when stanchions are stowed.

7.1.5 The top of stanchions may be provided with a coupling for stowage of socket plugs when stanchions are in use. See Fig. 4.

8. Dimensions and Tolerances

8.1 Dimensions for Type I—Two course portable flush deck stanchions shall be in accordance with Fig. 1.

8.2 Dimensions for Type II—Three course portable flush deck stanchions shall be in accordance with Fig. 2.

8.3 The dimensions are as indicated.

8.4 Socket, socket plug, stanchion, and coupling shall have tolerances in accordance with ANSI B16.15. All other dimensions shall have a tolerance of ±¼ in. (6.35 mm).

9. Workmanship, Finish, and Appearance

9.1 Stanchions shall be free of weld spatter, slag splinters, sharp edges, burrs, projections, and other defects hazardous to personnel.

9.2 Galvanizing destroyed after fabrication shall be repaired by the application of cold-galvanizing compound.

10. Testing

10.1 Hammer test deck sockets for soundness and strength.

10.2 Test at least one stanchion of each platform or deck by application of a load horizontally in accordance with the methods in “Strength and Stiffness of Metal Railing Systems and Rails for Buildings.”

11. Packaging

11.1 Loose hardware shall be packaged and wired to stanchion.

12. Keywords

12.1 deck stanchions; portable intermediate flush deck stanchion; stanchions

Standard Specification for
Docking/Drain Plug and Boss Assemblies [Metric]1

This standard is issued under the fixed designation F 991M; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification provides design, construction, and
purchasing criteria for docking/drain plug and boss assemblies.
1.2 Assemblies are intended for installation in shell, rudder,
and tank bottom plate from 8 through 38 mm.
1.3 Assemblies shall be installed at the lowest point of a
tank or rudder for draining during dry docking.
1.4 The values stated in SI units are to be regarded as the
standard.

2. Referenced Documents
2.1 ASTM Standards: 2
B 164 Specification for Nickel-Copper Alloy Rod, Bar, and
Wire
2.2 Other Documents:
ABS Rules for Building and Classing Steel Vessels3
ANSI B2.1 Standard Pipe Threads Except Dryseal4

3. Classification
3.1 Docking plugs and bosses shall be classified as follows:
3.1.1 Type I—Docking plug and bosses for plating from 8 to
15 mm (see Fig. 1).
3.1.2 Type II—Docking plug and bosses for plating greater
than 15 to 38 mm (see Fig. 2).

4. Ordering Information
4.1 Orders for material under this specification shall include
the following:
4.1.1 ASTM designation and year of issue.
4.1.2 Type (See Section 3).
4.1.3 Optional nonstandard materials.

5. Materials and Manufacture
5.1 Materials:
5.1.1 Boss—ABS Grade A or B, plate or bar.
5.1.2 Plug—Specification B 164 rod or bar.
5.1.3 Other materials may be substituted to suit hull con-
struction as approved by regulatory bodies.
5.2 Manufacture:
5.2.1 Plugs and bosses shall be machined.
5.2.2 Threads shall be in accordance with ANSI B2.1.

6. Dimensions and Tolerances
6.1 Dimensions shall be as indicated in Fig. 1 and Fig. 2.
6.2 Tolerance shall be ±1.5 mm.
6.3 Mass shall be as follows:

<table>
<thead>
<tr>
<th></th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boss</td>
<td>1.6 kg</td>
<td>5.7 kg</td>
</tr>
<tr>
<td>Plug</td>
<td>0.6 kg</td>
<td>1.0 kg</td>
</tr>
<tr>
<td>Total</td>
<td>2.2 kg</td>
<td>6.7 kg</td>
</tr>
</tbody>
</table>

7. Installation
7.1 All welding shall be to the standards of the Rules for
Building and Classing of Steel Vessels (ABS).
7.2 Threads shall be adequately protected during installa-
tion.
7.3 Fill plug face with portland cement or other suitable
compound and finish flush with face of boss.
7.4 Boss shall be inserted so that drain grooves run forward
and aft.
7.5 Plugs shall not be installed near large structural discon-
tinuities.
7.6 Adjacent shell plating weld joint preparation shall be as
required to ensure full penetration.

8. Keywords
8.1 boss assemblies; docking/drain plug; drydocking; rud-
der; shell; tank bottom plate

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.01 on Structures.

2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

3 Available from American Bureau of Shipping (ABS), ABS Plaza, 16855 Northchase Dr., Houston, TX 77060.

FIG. 1 Type I

130 mm DIAMETER HOLE
IN SHELL PLATING (See 7.6)

BOTTOM VIEW

127 mm DIAMETER

19 mm

3 mm x 45° BEVEL

1 1/2 - 11 x 2.309 mm (1 1/2 NPT)
NPT DRILL AND TAP BOSS

Section "A-A" (see 7.6)

FIG. 1 Type I
Standard Specification for Valve Label Plates

This standard is issued under the fixed designation F 992; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the materials, dimensions, inscription, and methods of inscribing for shipboard valve label plates.

1.2 Fasteners shall be ordered separately and are not included in this specification.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:
A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
B 36 Specification for Brass Plate, Sheet, Strip, and Rolled Bar
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
B 580 Specification for Anodic Oxide Coatings on Aluminum
D 709 Specification for Laminated Thermosetting Materials
2.2 Other Documents:
American Bureau of Shipping Rules for Building and Classing Steel Vessels
ANSI Y1.1 Abbreviations

3. Classification

3.1 Label plates shall be classified by type, grade, class, size, and letter size in accordance with material and method of inscribing, method of attachment, thickness of sheet, strip, or plate, dimensions, and letter size to be used.

3.2 Types and Materials:
3.2.1 Type I—Anodized aluminum, engraved.
3.2.2 Type II—Anodized aluminum, metal photo.
3.2.3 Type III—Stainless steel, engraved.
3.2.4 Type IV—Brass, engraved.
3.2.5 Type V—Plastic, engraved.
3.3 Grades and Methods of Attachment:
3.3.1 Grade A—Adhesive on metal bracket (backing plate) (Sizes A through J).
3.3.2 Grade B—Metal strapping or screw (Sizes A through J).
3.3.3 Grade C—Welding (Sizes A through J) See also the American Bureau of Shipping Standards.
3.3.4 Grade D—Secured by handwheel nut (Sizes K through R).
3.3.5 Grade E—Connection to valve stem, bonnet, or flange (Size S).
3.4 Class and Thickness:
3.4.1 Class 1—1/8 in.
3.4.2 Class 2—16 gage.
3.4.3 Class 3—20 gage.
3.4.4 Class 4—24 gage.
3.5 Size and Dimensions:
(length by width) or (outside diameter (OD) by inside diameter (ID)).
3.5.1 Size A—Rectangular 2 by % in.
3.5.2 Size B—Rectangular 2 by % in.
3.5.3 Size C—Rectangular 3 by % in.
3.5.4 Size D—Rectangular 3 by % in.
3.5.5 Size E—Rectangular 3 by % in.
3.5.6 Size F—Rectangular 4 by % in.
3.5.7 Size G—Rectangular 4 by % in.
3.5.8 Size H—Rectangular 4 by % in.
3.5.9 Size J—Rectangular 4 by % in.
3.5.10 Size K—Circular % in.
3.5.11 Size L—Circular % in.
3.5.12 Size M—Circular % in.
3.5.13 Size N—Circular 2 by % in.
3.5.14 Size P—Circular 2 by % in.
3.5.15 Size R—Circular 3 by % in.
3.5.16 Size S—Rectangular, 5 by % in. with % -in. diameter hole (see Fig. 3). (To be used with Type 3, Grade E only).
3.6 Letter Size:
4. Ordering Information

4.1 Orders for material under this specification shall include the following:
4.1.1 ASTM Designation and year of issue.
4.1.2 Type.
4.1.3 Grade.
4.1.4 Class.
4.1.5 Size.
4.1.6 Letter size.
4.1.7 Color of lettering (if other than default color black, standard red words, or white when plastic is used).
4.1.8 Inscription (as to be put on label).
4.1.9 Optional characteristics
4.1.9.1 A first option is to indicate "to suit" instead of a size of plate when ordering and the engraver will fit the plate to suit the applicable requirements.
4.1.9.2 A second option is to indicate "to suit" instead of a letter size when ordering and the engraver will fit the lettering (minimum of 1/8-in. letter size) onto the plate size chosen.
4.1.9.3 When nonstandard colors are needed for the label plates, the purchaser should specify.
4.1.9.4 When a letter style other than gothic lettering or arabic numerals is required, the purchaser should specify.

5. Materials and Manufacture

5.1 Materials:
5.1.1 Stainless steel, Specification A 167, Type 316.
5.1.2 Brass, Specification B 36, UNSC 26000.
5.1.3 Aluminum, Specification B 209, Alloy 5052.
5.1.4 Plastic, Specification D 709, Grade ES.
5.1.5 Spar varnish.
5.2 Manufacture:
5.2.1 Holes shall not be provided in rectangular plates unless the method of attachment (grade) is Grade B. In this case approximately ½-in. left and right margins shall be provided.
5.2.2 Edges of label plates shall be smooth.
5.2.3 Letters (engraved or metal photo), except as noted in 6.4, shall be black and the background natural. When plastic label plates are used, the core (lettering) shall be white and the outer layer (background) shall be black.
5.2.4 When sea valve label plates are used, or when cautionary words such as “Danger” and “Warning” or fuel words are part of the inscription, the lettering (engraved or metal photo) shall be red and the background natural. When plastic label plates are used, the core of the plate (lettering) shall be white and the outer layer (background) shall be red.
5.2.5 The front of aluminum label plates shall be coated with moisture-resistant spar varnish.
5.2.6 Engraved plates shall be engraved to a minimum depth of 0.008 in. When plastic label plates are used, the depth of engraving shall be sufficient to ensure uniform penetration of the top layer.
5.2.7 A symmetrical and well-balanced arrangement of letters and lines shall be attained with maximum legibility.
5.2.8 Gothic lettering and arabic numerals shall be used unless specified otherwise.
5.2.9 For circular label plates, a ¼-in. border shall be used when plates are under 2 in. in outside diameter; otherwise, a 1/8-in. border shall be used.
5.2.10 Aluminum plates shall be coated in accordance with Specification B 580.

6. General Requirements

6.1 Inscription on label plates shall include the system identification number, valve identification number, and the function of the valve. The pressure in line, where the line is coming from or going to, or both, may be included along with any other pertinent information.
6.2 When using label plates without backing, the minimum thickness shall be 20 gage.
6.3 Exterior label plates shall be stainless steel with a minimum thickness of 16 gage (SST gage, 0.0595 in.) except as noted in 6.4.
6.4 Exterior label plates for valve deck access boxes shall be a minimum of 1/8-in. thickness attached by seal welding as close as possible to the terminal. Label plate material shall be compatible with the deck or bulkhead material.
6.5 Label plates shall be located to ensure maximum visibility.
6.6 When a valve is installed behind an access panel or above a ceiling, an additional label plate shall be installed where normally visible as well as a label plate on the valve itself.
6.7 When using the stainless steel Grade D label plate, the plate shall be attached to the valve stem, bonnet, or flange bolt as appropriate.
6.8 Abbreviations shall be in accordance with ANSI Y1.1.
6.9 The use of 24-gage metal is limited to the use where anodized aluminum is used as the label metal and the method of attachment is Grade A. The metal bracket can be shaped such as Size S.
6.10 When circular label plates are used, it is the purchaser’s responsibility to choose title lengths and letter sizes such that the engraving will not be hidden by any valve components.
6.11 Adhesive-backed plates shall not be used on curved surfaces, surfaces not solid, or where the temperature could exceed 250°F.
6.12 Electrically insulated material shall be used as a backing when metal label plates are attached to bare valves or piping to prevent electrolytic corrosion between dissimilar metals.

7. Dimensions and Tolerances

7.1 Dimensions are as indicated in Fig. 1, Fig. 2, and Fig. 3.
7.2 Tolerances are ±1/8 in., except hole location ±1/2 in., engraving depth +0.002, −0.000 in., and letter size ±1/2 in.
8. Keywords

8.1 label plate; marine technology; ships; valve label plate

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1. Scope
1.1 This specification covers the application, design, and materials for valve locking devices.
1.2 Locking devices Types I and II described in this specification are designed to secure the valve in a fully opened or completely closed position.
1.3 This specification does not apply to valves equipped with locking devices from the valve manufacturer, unless this standard is invoked in the procurement ordering data for the valve or its locking device, or both.
1.4 This specification is intended to supersede NASEA drawing S4824-1385509. However, cancellation of that drawing and adoption of this specification can only be effected by the navy.

2. Referenced Documents
2.1 ASTM Standards:
A 36/A36M Specification for Carbon Structural Steel
A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
A 492 Specification for Stainless Steel Rope Wire
A 668/A 668M Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
B 580 Specification for Anodic Oxide Coatings on Aluminum
F 708 Practice for Design and Installation of Rigid Pipe Hangers
2.2 Other Documents:
ANSI B18.1 Small Solid Rivets
American Welding Society D1.1 on Steel

3. Classification
3.1 Valve locking devices shall be classified by the following types and grades in accordance with the method of locking and material used.
3.2 Types:
3.2.1 Type I—Wire rope assembly (see Fig. 1 Fig. 2).
3.2.2 Type II—Handwheel latch (see Fig. 3 Fig. 4).
3.2.3 Type III—Locking shield (see Fig. 5).
3.3 Grades:
3.3.1 Grade A—Stainless steel, Specification A 167, Type 316.
3.3.2 Grade B—Anodized aluminum, Specification B 209, Alloy 5052.
3.3.3 Grade C—Carbon steel, commercial quality steel (see Specification A 36/A36M).

4. Ordering Information
4.1 Orders for material under this specification shall include the following:
4.2 ASTM Designation and year of issue.
4.3 Type.
4.4 Grade.
4.5 Padlock Size (if necessary).
4.6 Rubber Coating (if necessary).
4.7 Necessary Dimensions:
4.7.1 Type I:
4.7.1.1 Length of wire strand.
4.7.1.2 Diameter of pipe.
4.7.2 Type II:
4.7.2.1 Maximum height (fully opened).
4.7.2.2 Minimum height (fully closed).
4.7.2.3 Handwheel thickness.
4.7.2.4 Handwheel depth.
4.7.2.5 Diameter at location of attachment.

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9 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.
4.7.3 Type III:
4.7.3.1 Depth.
4.7.3.2 Height.
4.7.3.3 Width.

4.7.3.4 Outside diameter (OD) of pipe.
5. Materials and Manufacture

5.1 Materials:

5.1.1 Type I Materials:

5.1.1.1 Pipe Clamp—Indicate diameter, similar to Practice F 708, Fig. 1, material specified by grade.

5.1.1.2 Ring Link—Size to be not less than clearance shown in Practice F 708, Table 3, Column F, material specified by grade.

5.1.1.3 Common Wire Strand—\(\frac{3}{16}\)-in. diameter, seven strands of seven wires each, stainless steel, Specification A 492, Alloy 316.

5.1.1.4 Tiller Rope Clamp—\(\frac{3}{16}\)-in. cable size, manufacturer, stainless steel (optional).

5.1.1.5 Rigid Eye Spring Hook—\(\frac{3}{8}\)-in. eye diameter, \(\frac{1}{2}\)-in. snap opening, plated forged steel, Specification A 668/A 668M, Class D.

5.1.1.6 Sleeve—Swaging, oval, for \(\frac{3}{16}\)-in. diameter wire rope, copper.

5.1.2 Type II Materials:

5.1.2.1 Modified Pipe Clamp—Indicate diameter, similar to Practice F 708, Fig. 1, material specified by grade.

5.1.2.2 Flat Head Rivet—\(\frac{1}{4}\)-in. nominal size, ANSI B18.1, material specified by grade.

5.1.2.3 Single Acting Quick Release Pin—\(\frac{1}{4}\)-in. nominal size by \(\frac{3}{16}\)-in. grip, stainless steel, Specification A 167, Type 316.

5.1.2.4 Lanyard—Wire rope, \(\frac{1}{8}\)-in. diameter, seven strands of seven wires each, 12 in. long, stainless steel Specification A 492, Alloy 316.

5.1.2.5 Sleeve—Swaging, oval, for \(\frac{1}{8}\)-in. diameter wire rope, copper.

5.1.2.6 Lanyard Clip—Flatbar, \(\frac{1}{16}\) in. thick by 1 in. wide by \(1\frac{1}{2}\) in. long, stainless steel, Specification A 167, Alloy 316.

5.1.2.7 Lever Arm—Size to suit, 16-gage material specified by grade.

5.1.3 Type III Materials:

5.1.3.1 Plate—Indicate size, 16 gage, material specified by grade.

5.1.3.2 Single-Acting Quick Release Pin—\(\frac{3}{8}\)-in. nominal size by \(\frac{1}{2}\)-in. grip, stainless steel, Specification A 167, Type 316.

5.1.3.3 Lanyard—Wire rope, \(\frac{1}{8}\)-in. diameter, seven strands of seven wires each, 12 in. long, stainless steel, Specification A 492, Alloy 316.

5.1.3.4 Sleeve—Swaging, oval, for \(\frac{1}{8}\)-in. diameter wire rope, copper.

5.1.3.5 Lanyard Clip—Flatbar, \(\frac{1}{16}\) in. thick by 1 in. wide by \(1\frac{1}{2}\) in. long, stainless steel, Specification A 167, Alloy 316.

5.1.3.6 Lockbar—\(\frac{3}{8}\) in. wide by length to suit by \(\frac{1}{16}\) in. thick, material specified by grade.

5.2 Manufacture:

5.2.1 Edges of the locking device shall be smooth. The devices shall also be free of defects and burrs.

5.2.2 Welds shall be done in accordance with American Welding Society D1.1.

6. General Requirements

6.1 A label plate shall be installed on or near the locking device to instruct the operator on usage.

6.2 When noise reduction is necessary, the contacting parts of the locking device shall have a rubber coating or lining.

6.3 The locking device must be able to lock the valve in both the fully opened and completely closed positions.

6.4 When using Type I, the cable shall be installed sufficiently tight to prevent more than slight movement of the handwheel in a direction opposite of the designed position but not so tight as to place the cable in tension.
6.5 The position of the locking device on the handwheel shall be as to resist movement of the valve stem.

6.6 Type II dimensions shall be used to determine the size of the lever arm, extension on pipe hanger, and the position of the locking holes and slot.

6.7 When specified by the purchaser, a padlock can be used instead of the quick release pin or spring hook.

7. Dimensions and Tolerances

7.1 Dimensions shall be as specified in the figures shown.

7.2 Tolerances are ±\(\frac{1}{16}\) in. except for drilled hole diameter for pin which shall be +\(\frac{1}{32}\) in., −0 in.

8. Keywords

8.1 locking device; marine technology; ship; valve; valve locking device
FIG. 5 Type III—Valve Cover Box
Standard Specification for Design and Installation of Overboard Discharge Hull Penetration Connections

This standard is issued under the fixed designation F 994; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers carbon steel overboard discharge hull penetrations for system piping of NPS 1 through NPS 24 (see Note 1).

Note 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as nominal diameter, size, and nominal size.

1.2 The minimum pipe schedule and reinforcement dimensions presented in Tables 1-6 are based on specifications in 46 CFR, 56.50-95 and Navy Design Data Sheet 100-1.

1.3 This specification does not include sea chest penetrations.

1.4 This specification does not include penetrations in protective plating.

2. Referenced Documents

2.1 ASTM Standards:
A 519 Specification for Seamless Carbon and Alloy Steel Mechanical Tubing

2.2 ANSI Standard:
B36.10 Welded and Seamless Wrought Steel Pipe

2.3 Military Document:
MIL-STD-1689 Fabrication, Welding, and Inspection of Ships Structure

2.4 Other Documents:
Title 46 Code of Federal Regulations (CFR), Subchapter F, Marine Engineering
Department of the Navy, Bureau of Ship Design Data Sheet 100-1

3. Classification

3.1 Type I—Nonreinforced penetrations. Table 1 provides minimum schedules for the penetration pipe. See Fig. 1 for details of the penetration.

3.2 Type II—Doubler plate-reinforced penetrations. Table 2 provides minimum dimensions for doubler plates.

3.2.1 Class 1—Inboard doubler plates. (Fig. 2)
3.2.2 Class 2—Outboard doubler plates. (Fig. 3)

3.3 Type III—Insert plate-reinforced penetrations. Table 3 provides minimum dimensions for insert plates.

3.3.1 Class 1—Single-bevel insert plates. (Fig. 4)
3.3.2 Class 2—Double-bevel insert plates. (Fig. 5)

3.4 Type IV—Sleeve-reinforced penetrations. Fig. 6 details sleeve-reinforced penetrations.

ABS Rules for Building and Clasing Steel Vessels

TABLE 1 Pipe Schedule for Type 1 Penetrations, NPS 1 Through NPS 24

<table>
<thead>
<tr>
<th>Penetration Pipe Size, NPS</th>
<th>Shell Plating Thickness (T), in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T 1/8</td>
</tr>
<tr>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>1 1/4</td>
<td>80</td>
</tr>
<tr>
<td>1 1/2</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>2 1/2</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>8</td>
<td>80</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>12</td>
<td>80</td>
</tr>
<tr>
<td>14</td>
<td>80</td>
</tr>
<tr>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>18</td>
<td>80</td>
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<tr>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>22</td>
<td>80</td>
</tr>
<tr>
<td>24</td>
<td>80</td>
</tr>
</tbody>
</table>

*See Fig. 1.*
Table 5 provides minimum dimensions for machined sleeves.

Table 5

<table>
<thead>
<tr>
<th>Penetrating Pipe Size, NPS, SCH</th>
<th>%</th>
<th>1/8</th>
<th>1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 80</td>
<td>1 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>1 1/4, 80</td>
<td>1 1/4 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>1 1/2, 80</td>
<td>1 1/2 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>2, 80</td>
<td>2 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>3, 80</td>
<td>3 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>4, 80</td>
<td>4 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
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<tr>
<td>5, 80</td>
<td>5 x 8</td>
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<td>1/4 x 8</td>
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<tr>
<td>6, 80</td>
<td>6 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
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<td>1/4 x 8</td>
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<td>10, 80</td>
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<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>12, 80</td>
<td>12 x 8</td>
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<tr>
<td>14, 80</td>
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<tr>
<td>16, 80</td>
<td>16 x 8</td>
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<td>1/4 x 8</td>
</tr>
<tr>
<td>18, 80</td>
<td>18 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>20, 80</td>
<td>20 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>22, 80</td>
<td>22 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>24, 80</td>
<td>24 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
</tbody>
</table>

A See Fig. 2 and Fig. 3.

Table 3 provides minimum dimensions for nonmachined sleeves.

Table 3

<table>
<thead>
<tr>
<th>Penetrating Pipe Size, NPS, SCH</th>
<th>%</th>
<th>1/8</th>
<th>1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 80</td>
<td>1 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>1 1/4, 80</td>
<td>1 1/4 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>1 1/2, 80</td>
<td>1 1/2 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>2, 80</td>
<td>2 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>3, 80</td>
<td>3 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>4, 80</td>
<td>4 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>5, 80</td>
<td>5 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
<tr>
<td>6, 80</td>
<td>6 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
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<tr>
<td>8, 80</td>
<td>8 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
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<tr>
<td>10, 80</td>
<td>10 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>12, 80</td>
<td>12 x 8</td>
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<td>1/4 x 8</td>
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<td>14, 80</td>
<td>14 x 8</td>
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<td>1/8 x 8</td>
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<tr>
<td>16, 80</td>
<td>16 x 8</td>
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<td>1/4 x 8</td>
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<td>18 x 8</td>
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<td>1/8 x 8</td>
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<td>20, 80</td>
<td>20 x 8</td>
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<td>1/4 x 8</td>
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<tr>
<td>22, 80</td>
<td>22 x 8</td>
<td>1/4 x 8</td>
<td>1/8 x 8</td>
</tr>
<tr>
<td>24, 80</td>
<td>24 x 8</td>
<td>1/8 x 8</td>
<td>1/4 x 8</td>
</tr>
</tbody>
</table>

A See Fig. 4 and Fig. 5.

3.4.1 Class 1—Sleeves of nonmachined steel tube. Table 4 provides minimum dimensions for nonmachined sleeves.

3.4.2 Class 2—Sleeves of machined steel tube or pipe. Table 5 provides minimum dimensions for machined sleeves.

3.4.3 Class 3—Sleeves of rolled steel flatbar or plate. Table 6 provides minimum dimensions for rolled sleeves.

4. Materials

4.1 Discharge pipe shall be of an acceptable material as specified by Title 46 CFR, 56.60-1.

4.2 Doubler and insert plates shall be of material with physical properties equal to or better than the reinforced shell plate.

4.3 Reinforcing sleeve material shall depend on the penetration pipe size:

5. General Requirements

5.1 Overboard discharges shall be combined to the maximum extent practicable to minimize the number of shell penetrations.

5.2 A minimum of 3 in. shall be maintained between the edge of penetrations and shell plate welding seams. Penetrations shall be located so as to provide sufficient space for...
5.6 Unfavorable flow characteristics may result when small diameter, extreme schedule penetration pipe is used in accordance with Table 1. In this case, minimum allowable schedule penetration pipe, with necessary reinforcement as specified in Tables 2-6, is suggested.

5.7 Penetration pipe extension past the shell plate shall be equal to the pipe wall thickness but not more than 3/8 in.

6. Welding

6.1 Welding shall be in accordance with Figs. 1-6 (see also ANSI B36.10).

6.2 Weld quality shall be in accordance with American Bureau of Shipping standards.

6.3 Fillet welds shall be equal to the penetration pipe wall thickness but not more than 3/8 in.

6.4 Weld quality for military vessels shall be in accordance with MIL-STD-1689.
### 7. Workmanship, Finish, and Appearance

7.1 Surface areas, corners, and discharge pipe ends shall be free of burrs and sharp edges.

### 8. Keywords

8.1 discharge hull penetration; hull penetration; marine technology; penetration connection; ships; system piping

---

**TABLE 6 Reinforcing Sleeve Dimensions, NPS 14 Through NPS 24 (Rolled Steel Flatbar or Plate)**

<table>
<thead>
<tr>
<th>Penetration Pipe Size, NPS, SCH</th>
<th>Sleeve Size, in.</th>
<th>Shell Plating Thickness (T), in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>14, 60 inner diameter wall thickness length</td>
<td>14/16 14/16 14/16 14/16 14/16 14/16 14/16 14/16</td>
<td>1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8</td>
</tr>
<tr>
<td>18, 40 inner diameter wall thickness length</td>
<td>18/16 18/16 18/16 18/16 18/16 18/16 18/16 18/16</td>
<td>3/4 3/4 3/4 3/4 3/4 3/4 3/4 3/4</td>
</tr>
</tbody>
</table>

---

*See Fig. 6.*

---

**FIG. 1 Type I: Penetration**

**FIG. 2 Type II, Class 1 Penetration: Inboard Doubler Plate**
FIG. 3 Type II, Class 2 Penetration: Outboard Doubler Plate

FIG. 4 Type III, Class 1 Penetration: Single-Bevel Insert Plate
FIG. 5 Type III, Class 2 Penetration: Double-Bevel Insert Plate

FIG. 6 Type IV Penetration: Reinforcing Sleeve
Standard Specification for Centrifugal Pump, Shipboard Use

This standard is issued under the fixed designation F 998; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the requirements applicable to the design and construction of centrifugal pumps for shipboard application. The three classes of service covered by this specification are as follows:

1.1.1 Class 1—Freshwater,
1.1.2 Class 2—Seawater, and
1.1.3 Class 3—Hydrocarbon pumps (less than 1500 SSU).

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Carbon Structural Steel
A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 276 Specification for Stainless Steel Bars and Shapes
A 494/A 494M Specification for Castings, Nickel and Nickel Alloy
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening
B 148 Specification for Aluminum-Bronze Sand Castings
B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire

B 271 Specification for Copper-Base Alloy Centrifugal Castings
B 369 Specification for Copper-Nickel Alloy Castings
B 505 Specification for Copper-Base Alloy Continuous Castings
B 584 Specification for Copper Alloy Sand Castings for General Applications
F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
F 1511 Specification for Mechanical Seals for Shipboard Pump Applications

2.2 ANSI Standards:

B1 ISO Metric Screw Threads (ANSI-B1 Report)
B1.1 Unified Screw Threads
B16.1 Cast Iron Pipe Flanges and Flange Fittings
B16.5 Steel Pipe Flanges, Flanged Valves and Fittings, 150, 300, 400, 600, 900, 1500 and 2500 lb.
B16.11 Forged Steel Fittings, Socket Welding and Threaded
B16.24 Bronze Flanges and Flanged Fittings, 150, 300lb

2.3 Hydraulic Institute Standards:

ANSI/HI 1.1-1.5 American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Applications and Operation
ANSI/HI 1.6 American National Standard for Centrifugal Pump Tests

2.4 AFBMA Standards:

9 Load Ratings and Fatigue Life for Ball Bearings
11 Load Ratings and Fatigue Life for Roller Bearings

2.5 ISO Standards:

ISO 9001 Quality Systems and Quality Assurance—Design/Development, Production, Installation and Service

3. Terminology

3.1 Definitions:

3.1.1 best efficiency point (BEP), n—the capacity and head in which the pump efficiency is the highest.
3.1.2 BHP, $n$—power delivered to the pump from the driver in brake horse power.

3.1.3 capacity, $n$—the total volume output per unit of time.

3.1.4 centrifugal pump, $n$—a kinetic machine converting mechanical energy into hydraulic energy through rotating motion.

3.1.5 close coupled pumps, $n$—in this arrangement, no coupling is provided between the pump and the motor shafts, and the pump housing is flange mounted to the motor. The pump impeller is directly mounted to the motor shaft.

3.1.6 coupled pumps, $n$—in this arrangement, the pump and the motor must use a coupling to transmit the power from the driver to the pump shaft.

3.1.7 gallons per minute (GPM), $n$—U.S. customary unit for capacity.

3.1.8 head, $n$—the expression of the energy content of the liquid referred to in any arbitrary datum. It is expressed in units of energy per unit of weight liquid. The measuring unit for head is foot (metre) of liquid.

3.1.9 head, total discharge, $n$—the sum of the pump’s discharge gauge head, the velocity head at the gauge connection, and the elevation difference between the pump centerline and the gauge centerline.

3.1.10 head, total, $n$—the measurement of energy increase per unit weight of the liquid, imparted to the liquid by the pump, and is the difference between the total discharge head and the total suction head.

3.1.11 head, total suction, $n$—the sum of the pumps suction gauge head, the velocity head at the gauge connection, and the elevation difference between the pump inlet centerline and the gauge centerline.

3.1.12 head, maximum rated, $n$—the most head a pump can generate with the correct impeller diameter for the service conditions.

3.1.13 hydrostatic test, $n$—applying static pressure to the assembled pump or pressure containing components to determine structural integrity of the unit.

3.1.14 maximum allowable working pressure, $n$—the maximum discharge pressure that could occur in the pump when it is operated at the rated speed and suction pressure for a given application.

3.1.15 maximum BHP rated impeller, $n$—the highest power required by a pump with the correct impeller diameter for the service condition.

3.1.16 minimum continuous flow, $n$—the lowest possible flow rate at which the pump can run without generating excessive heat within the unit or damage to the pump.

3.1.17 net positive suction head available (NPSHA), $n$—the total suction head absolute, determined at the first stage impeller datum, less the absolute vapor pressure of the liquid at a specific capacity.

3.1.18 net positive suction head required (NPSHR), $n$—the amount of suction head over vapor pressure required at the pump to prevent more than a 3% loss in total head from the first stage of the pump at a specific capacity.

3.1.19 nonmetallic materials, $n$—any material that would not be recognized as a metal. Examples include plastics, fiberglass resins, carbon fiber, fiberglass-reinforced vinyl ester, polytetrafluoroethylene (PTFE), or any similar material.

3.1.20 non-overloading power characteristics, $n$—this characteristic requires that the driver be sized for the highest possible power requirement from the pump.

3.1.21 OEM, $n$—original equipment manufacturer of the pump unit.

3.1.22 pounds per square inch absolute (PSIA), $n$—the U.S. customary measure of pressure with zero as a true absolute zero in pounds per square inch.

3.1.23 pounds per square inch gauge (PSIG), $n$—the U.S. customary measure of pressure with zero being adjusted to atmospheric pressure in pounds per square inch.

3.1.24 pump efficiency (Eff), $n$—the ratio of the energy imparted to the liquid by the pump to the energy supplied to the pump from the driver.

3.1.25 pump unit, $n$—a typical pump unit consists of a separate pump and driver, combined pump and driver (close coupled), coupling, and coupling guard, and may include a gear box and base plate.

3.1.26 rated point, $n$—applies to the capacity, head, net positive suction head, and speed of the pump as specified by the order.

3.1.27 specific gravity (Sp. Gr.), $n$—the ratio of the density of the liquid to the density of water at 64°F (17.8°C).

3.1.28 vapor pressure, $n$—the pressure exerted when a liquid is in equilibrium with its own vapor. The vapor pressure is a function of the substance and of the temperature.

3.1.29 viscosity, $n$—the resistance of a fluid to shear motion, its internal friction.

4. Ordering Information

4.1 Fig. 1 and Fig. 2 are provided for use by the procuring activity and the OEM. The sections of Fig. 1 and Fig. 2 marked “User Defined,” must be completed by the procuring activity and submitted with the request for bid. This will ensure that the potential bidder provides a pump unit that meets all performance, operational, and reliability requirements of the purchaser. The OEM will fill out all sections of Fig. 1 and Fig. 2 marked “OEM Defined,” and return the data sheet to the purchaser upon delivery of the pump.

4.2 For the convenience of the procuring activity, Fig. 1 and Fig. 2 are provided in both U.S. customary and SI versions.

5. Material

5.1 The materials cited in Table 1 are provided as a guide. Other materials may be substituted as approved by the purchasing activity and as specified in Fig. 1 and Fig. 2.

5.2 When selecting material combinations, the pump supplier shall take into consideration the conditions under which the various materials interact with each other. Material hardness shall be such that any rubbing, sliding, or tight clearance parts shall be selected so that no binding or galling occurs. Special care shall be taken with Class 2 pump materials that interact with each other in a seawater environment.

5.3 Consideration shall be given to the use of nonmetallic (composite) pump components where the use of that material
CENTRIFUGAL PUMP ORDERING DATA (ENGLISH)

FIG. 1 Centrifugal Pump Ordering Data (English)
# CENTRIFUGAL PUMP ORDERING DATA (METRIC)

<table>
<thead>
<tr>
<th>USER/CUSTOMER</th>
<th>OEM/BIDDER</th>
<th>DATE</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>CLASS (1 THRU 6)</th>
<th>NO. OF PUMPS</th>
<th>NO. OF DRIVERS (MOTORS/TURBINE)</th>
<th>ITEM NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATING CONDITIONS (PURCHASER-DEFINED)</td>
<td>PERFORMANCE (OEM-DEFINED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLUID</td>
<td>PERFORMANCE CURVE NO.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>°C RATED</td>
<td>RPM</td>
<td>NPSH (WATER)</td>
<td></td>
</tr>
<tr>
<td>°C MAX.</td>
<td>EFF</td>
<td>% BHP RATED</td>
<td></td>
</tr>
<tr>
<td>SP. GR. AT RATED PT.</td>
<td>MAX Kw RATED IMPELLER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL HEAD, (bar) RATED</td>
<td>MAX. HEAD RATED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAP. PRESS. AT RATED PT.</td>
<td>MAX DISCH. PRESS. (bar)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUCT. PRESS. (bar) MAX</td>
<td>MIN CONTINUOUS (Lpm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VISCOSITY AT RATED, Centistokes</td>
<td>TESTING (PURCHASER-DEFINED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPSHA, (bar)</td>
<td>☐ HYDRO TEST</td>
<td>☐ WITNESS</td>
<td>☐ NON-WITNESS</td>
</tr>
<tr>
<td>AMBIENT CONDITIONS</td>
<td>☐ MECH TEST</td>
<td>☐ WITNESS</td>
<td>☐ NON-WITNESS</td>
</tr>
<tr>
<td>PITCH</td>
<td>☐ PERF TEST</td>
<td>☐ WITNESS</td>
<td>☐ NON-WITNESS</td>
</tr>
<tr>
<td>ROLL</td>
<td>☐ NRSH</td>
<td>☐ WITNESS</td>
<td>☐ NON-WITNESS</td>
</tr>
<tr>
<td>LIST</td>
<td>☐ VIBRATION</td>
<td>☐ WITNESS</td>
<td>☐ NON-WITNESS</td>
</tr>
<tr>
<td>TRIM</td>
<td>☐ ACOUSTIC</td>
<td>☐ WITNESS</td>
<td>☐ NON-WITNESS</td>
</tr>
<tr>
<td>CONSTRUCTION (PURCHASER REQUIREMENTS)</td>
<td>☐ DISMANTLE/INSPECT AFTER TEST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ OTHER:</td>
<td>☐ TEST REPORTS REQUIRED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ SPLIT: ☐ RADIAL</td>
<td>MATERIALS (PURCHASER DEFINED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ AXIAL</td>
<td>CASING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAINTING/COATINGS SPECIFICATION:</td>
<td>IMPELLER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ OTHER:</td>
<td>WEAR RINGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACOUSTICS SPECIFICATION:</td>
<td>SHAFT/SLEEVE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dB(A) CENTERBAND VALUES</td>
<td>GLAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONNECTIONS:</td>
<td>BASEPLATE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ DRAIN/VENT</td>
<td>☐ OTHER:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ INLET GAGE</td>
<td>INSPECTIONS (PURCHASER-DEFINED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ DISCHARGE GAGE</td>
<td>☐ IN-PROCESS REQUIRED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ IN ACCORDANCE WITH ASTM F1511</td>
<td>☐ FINAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ IN ACCORDANCE WITH</td>
<td>☐ ____ DAYS NOTE, REQ'D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## PUMP DETAILS (OEM-DEFINED)

| PRESS: ☐ MAX. ALLOW. | MATERIALS (PURCHASER DEFINED) |
| MAX. | CASING |
| bar | IMPELLER |
| °C HYDRO TEST | WEAR RINGS |
| bar | SHAFT/SLEEVE |
| IMPELLER DIA. RATED | GLAND |
| MAX | BASEPLATE |
| IMPELLER TYPE | OTHER: |
| BEARING TYPES: | INSPECTIONS (PURCHASER-DEFINED) |
| RADIAL | ☐ IN-PROCESS REQUIRED |
| THRUST | ☐ FINAL |
| LUBE: ☐ OIL | ☐ ____ DAYS NOTE, REQ'D |
| ☐ GREASE | ☐ ADDITIONAL |
| ☐ PERM GREASE | REQUIREMENTS |
| COUPLING: MFR. | COMMENTS (OEM & PURCHASER DEFINED) |
| ☐ MODEL | ☐ CUSTOMER/USER |
| DRIVER HALF MTD. BY: | LOCATION | CUSTOMER P.O. NO. |
| ☐ PUMP MFR. | ITEM NO (S): | EQUIP. NO (S) |
| ☐ DRIVER MFR. | FACTORY ORDER NO (S): | PUMP SERIAL NO (S) |
| ☐ PURCHASER | ISSUED BY | REVISED BY |
| MECH. SEAL: ☐ MFR. & MODEL | DATE | DATE |
| MATERIAL CODE | (WORD 6.0, DOCS/FCE/002) |

### DRIVER (PURCHASER-DEFINED)

<table>
<thead>
<tr>
<th>☐ MOTOR</th>
<th>☐ TURBINE</th>
<th>☐ OTHER</th>
<th>SUPPLIED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHP</td>
<td>RPM</td>
<td>FRAME</td>
<td>VOLTS/PHASE/HERTZ</td>
</tr>
<tr>
<td>MFR</td>
<td>BEARINGS</td>
<td>SERVICE FACTOR</td>
<td></td>
</tr>
<tr>
<td>TYPE</td>
<td>INSULATION</td>
<td>AMPS: FL</td>
<td>LR</td>
</tr>
<tr>
<td>LUBE</td>
<td>TEMP. RISE °C</td>
<td>ENCL.</td>
<td>ORIENTATION (REL. TO PUMP INLET)</td>
</tr>
<tr>
<td>FOR STEAM TURBINE DRIVER:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INLET PRESS.</td>
<td>EXH. PRESS.</td>
<td>STEAM TEMP.</td>
<td>WATER RATE</td>
</tr>
</tbody>
</table>

### OTHER:

#### PUMP DATA (AFTER PRODUCTION BY OEM)

<table>
<thead>
<tr>
<th>CUSTOMER/USER</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM NO (S):</td>
<td>EQUIP. NO (S)</td>
</tr>
<tr>
<td>FACTORY ORDER NO (S):</td>
<td>PUMP SERIAL NO (S)</td>
</tr>
</tbody>
</table>

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FIG. 2 Centrifugal Pump Ordering Data (Metric)
can benefit the operation and maintenance of the pump. Purchaser approval must be obtained for the use of nonmetallic materials.

6. General Requirements

6.1 Pumps shall be designed to meet all operational requirements of the intended service and be constructed in such a manner as to allow for reliable operation and maintenance.

6.2 Pumps shall be selected to operate at or near the best efficiency point (BEP) on the head-capacity curve.

6.3 Motors shall have power ratings, including a service factor, if any, at least equal to 125% of pump brake-horsepower at rated design condition for motors less than 30 hp, 115% of pump brake-horsepower at rated design condition for motors rated between 30 and 75 hp and 110% of pump brake-horsepower at pump-rated design condition for motors greater than 75 hp. The power required at pump-rated conditions shall not exceed the motor nameplate horsepower rating.

6.4 Pumps shall be designed for a shipboard environment including both pitch and roll conditions specified by the purchaser in Fig. 1 and Fig. 2. Pumps shall also be capable of sustained operation at the maximum angles of list and trim specified in Fig. 1 and Fig. 2.

6.5 For horizontal pumps, the pump and driver shall be mounted on a common base of sufficient strength and stiffness to allow for proper alignment and operation. Where necessary to maintain proper alignment, dowels or fitted bolts shall be provided.

6.6 All vertical pumps shall be entirely supported by a horizontal foundation or a vertical ship structure, but not both. Where necessary, the upper portion of the pump unit may be bolted to a frame erected on the horizontal foundation.

6.7 Bedplates for Class 3 pumps shall be equipped with driprims and drain connections.

6.8 Horizontal pumps of the coupled type shall be driven through a flexible coupling. Coupled vertical pumps may be connected to their drivers by a flexible or rigid coupling. Couplings between the pump and driver shall be keyed to both shafts.

### TABLE 1 Material Specifications

<table>
<thead>
<tr>
<th>Class 1: Freshwater</th>
<th>Class 2: Seawater</th>
<th>Class 3: Hydrocarbon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Casing and Pressure Boundary Parts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronze (Specification B 584, Alloy C90500, C92200, or C87500)</td>
<td>Corrosion-resistant Duplex Alloy (Specification A 890/A 890M, Grade CD4MCu)</td>
<td>Bronze (Specification B 584, Alloy C90500, C92200, or C87500)</td>
</tr>
<tr>
<td>Stainless Steel (Specification A 743/A 743M, CF8M)</td>
<td>Ni-Al Bronze (Specification B 148, Alloy C95500 or C95800)</td>
<td>Stainless Steel (Specification A 743/A 743M, CF8M, J92900)</td>
</tr>
</tbody>
</table>

| **Shaft and Rotor Parts** | | |
| Stainless Steel (Specification A 582/A 582M, Cond, Alloy S41600) | Stainless Steel (Specification A276, S31600) | Stainless Steel (Specification A58/A 582M A, Alloy S41600) |
| Nickel-copper alloy (Specification B 164, UNS N04400 or N04405) | Nickel-copper Alloy (Monel) (Specification B 164, UNS N04400) | |
| Composite* (shaft sleeves only) | Composite* (shaft sleeves only) | |

| **Impellers** | | |
| Bronze (Specification B 584, Alloy C90500, C92200, or C87500) | Corrosion-resistant Duplex Alloy (Specification A 890/A 890M, Grade CD4MCu) | Bronze (Specification B 584, Alloy C90500, C92200, or C87500) |
| Stainless Steel (Specification A 743/A 743M, Grade CF8M or CF8) | Ni-Al Bronze (Specification B 148, UNS C95500 or C95800) | Stainless Steel (Specification A 743/A 743M, Grade CF8M or CF8) |
| Composite* | Composite* | |

| **Wear Rings** | | |
| Bronze (Specification B 271, B 505 or B 584) | Stainless Steel (Specification A 747, CB7Cu-1, Cond H1150, J92180) | Bronze (Specification B 271, B 505, or B 584) |
| Composite* | Bronze (Specification B 271, B 505 or B 584) | Composite* |

| **Casting Fasteners** | | |
| Corrosion-resisting steel (Specification A 193/A 193M, Grade B8M and A 194/A 194M, Grade 8M) | Monel (Specification F 468, Alloy 400) | Corrosion-resisting steel (Specification A 193/A 193M, Grade B8M and A 194/A 194M, Grade 8M) |
| Structural Steel (Specification A 36/A 36M) | Structural Steel (Specification A 36/A 36M) | Structural Steel (Specification A 36/A 36M) |

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*Materials used for seawater services may also be used for Class 1 and 3 service pumps. Galvanic compatibility must be taken into consideration when choosing allowable materials.

*Material property of composites must be suitable for pump service life and intended service.
6.9 All pump units shall incorporate guards over the couplings, belts, and other external rotating parts. The guards shall prevent personnel contact with the rotating elements. Guards shall be rigid enough to support a 200-lb (88-kg) person.

6.10 Pump and driver seating surfaces of mounting bedplates, bracket mounting plates, or other mounting arrangements shall be machined.

6.11 Sufficient means shall be provided for attaching conventional lifting gear for the installation, removal, and maintenance of both the pump and driver.

6.12 Pumps with face-mounted motors shall be arranged such that there are four possible orientations of the motor to pump.

6.13 Shaft alignment between the pump and driver will be specified by the OEM to allow the pump unit to operate within the vibration limits set in Section 8 over the expected service life of the pump.

6.14 Direction of rotation shall be indicated on the pump by either an arrow cast into the pump casing or by a direction arrow plate permanently attached to the pump.

6.15 The driver type and requirements shall be specified in Fig. 1 and Fig. 2.

7. Pump Design

7.1 Pump inlet and outlet connections shall be flanged in accordance with ANSI B16.1, B16.5, B16.11, or B16.24.

7.2 Pump casings, except for close-coupled pumps, shall be arranged so that the rotating components can be removed without disturbing the driver or the suction and discharge connections.

7.3 The pump casings shall be provided with bosses drilled and tapped or socket welded and flanged for suction, discharge pressure gage, and vent and drain connections if specified in Fig. 1 and Fig. 2 (refer to Fig. 1 and Fig. 2 for type and size). All connections shall be plugged or blank flanged using material suitable for design conditions.

7.4 Coupled pumps shall be equipped with radial and thrust bearings to support the rotor and counteract any unbalanced forces in the pump and ensure that the pump will operate satisfactorily over the pump’s entire design range.

7.5 Close coupled pumps and rigidly coupled vertical pumps shall have radial and thrust bearings located in the driver that are capable of supporting the rotating assembly and counteracting any unbalanced forces in the pump unit.

7.6 Bearings shall be securely fitted by snap rings, shoulders, or other means to prevent axial movement within the bearing housing. Bearing housings shall be integral or bolted to the pump case to maintain internal alignment of components and external alignment between the pump and driver. Bolted connections require fitted bolts, dowels, or rabbot fit to ensure alignment of the bearing housing to the casing.

7.7 Journal and thrust bearings may be of the fluid film or rolling element (antifriction) type. The bearings may be sealed and self- or externally lubricated or may be lubricated by the process fluid.

7.8 Rolling element bearings shall be selected in accordance with AFBMA Standards 9 or 11, or both, and shall have a calculated minimum L10 life of 15 000 h.

7.9 Unless otherwise specified in Fig. 1 and Fig. 2, all pumps shall be equipped with mechanical seals in accordance with Specification F 1511. The installation shall ensure that adequate circulation of liquid at the seal faces occurs to minimize deposits of foreign matter and to provide adequate lubrication of the seal faces.

7.10 Material selection shall be in accordance with Section 5.

7.11 Separate pressure boundary parts such as casing halves, suction heads, and end covers shall be attached to the pump casing using rabbot fits, dowel pins, or fitted bolts to ensure component alignment.

7.12 Screw threads shall conform to ANSI B1.1. Metric screw threads shall conform to ISO Metric Screw Threads (ANSI B1 Report.)

8. Performance Requirements

8.1 The operating conditions of the pump shall be as specified in Fig. 1 and Fig. 2.

8.2 The NPSHR of the pump as determined by the Hydraulic Institute Standards (ANSI/HI 1.1-1.5) shall not exceed the NPSHA that is specified at the rated condition.

8.3 Pumps that handle liquids more viscous than water shall have their water performance corrected in accordance with the Hydraulic Institute Standard (ANSI/HI 1.1-1.5).

8.4 The internally excited vibration levels of the pump unit shall not exceed the requirements of the centrifugal pump test standards of the Hydraulic Institute (ANSI/HI 1.1-1.5).

8.5 The acoustic levels of the pump shall not exceed those specified in Fig. 1 or Fig. 2 when measured in accordance with the centrifugal pump test standards of the Hydraulic Institute (ANSI/HI 9.1-9.5).

8.6 Pressure containing parts shall be capable of withstanding a pressure of at least 1.5 times the maximum allowable design pressure.

9. Painting and Coatings

9.1 Painting—External unmachined and nonmating machined surfaces (except for stainless steel) shall be thoroughly cleaned and painted with a hydrocarbon-resistant, anticorrosive (lead and chromate free) primer and topcoat. Heat-resistant paint requirements, if any, will be specified in Fig. 1 and Fig. 2.

9.2 Painting external surfaces of nonferrous parts and components is not required but is permissible to avoid excessive masking. Identification plates shall not be painted or oversprayed.

10. Equipment Identification Plates

10.1 Identification plates shall be made of a corrosion-resistant material that will last throughout the service life of the pump. The identification plate must be securely attached to each pump.

10.2 The pump identification plate shall contain, at a minimum, the following information:

10.2.1 Manufacturer’s name,
10.2.2 Manufacturer’s model number and size,
10.2.3 Manufacturer’s serial number,
12. Technical Documentation

12.1 Unless otherwise specified, each pump shall include an instruction book that shall be composed of the following:

12.1.1 Unit description;
12.1.2 Installation instructions;
12.1.3 Operating instructions;
12.1.4 Maintenance procedures (including complete pump disassembly and assembly);
12.1.5 Outline dimension drawing, including weight;
12.1.6 Typical cross-sectional assembly drawing and list of materials;
12.1.7 Performance curve that plots total head, efficiency, NPSH, (if required), and brake horsepower as a function of capacity; and
12.1.8 List of fluids with material safety data sheets (MSDS).

12.2 Submittal Documents—Proposal documents shall consist of the following:

12.2.1 Outline dimension drawing with weight and center of gravity;
12.2.2 Typical cross-sectional drawing and list of materials;
12.2.3 Performance curve which plots total head, efficiency, water NPSH, and brake horsepower as a function of capacity; and
12.2.4 List of recommended spare parts.

13. Packaging and Preservation

13.1 All openings shall be sealed with covers. Small piping (1 in. or less) may be sealed with tape. Cover design shall preclude the makeup of connecting piping with covers in place.
13.2 Each unit shall be crated and braced. Small piping shall be secured to prevent damage during shipment.
13.3 Internal surfaces subject to rusting shall be coated with suitable rust preventative.

14. Quality Assurance

14.1 The manufacturer shall have a certified ISO 9001 quality system.

15. Keywords

15.1 bilge and ballast pump; boiler feed pump; centrifugal; centrifugal pump; condensate pump; freshwater pump; hydrocarbon pump; impeller; marine pump; pump; seawater pump
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. When the contract or order invokes a supplement item listed in this section and which may be in conflict with the requirements of Specification F 998, the requirements of the supplement shall prevail. The manufacturer and purchaser shall agree upon details of the supplementary requirements. The manufacturer shall perform the specified tests before shipment of the pump.

S1. Referenced Documents

S1.1 ASTM Standard:
B 473 Specification for UNS N08020, UNS08024, and UNS N08026 Nickel Alloy Bar and Wire
S1.2 ANSI Standard:
S2.19 Balance Quality Requirements of Rigid Rotors, Part 1: Determination of Permissible Residual Unbalance
S1.3 ISO Standard:
281 Rolling Bearings—Dynamic Load Ratings and Rating Life
S1.4 Military Standards:
MIL-STD-167–1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-740 Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment
MIL-S-901 Shock Tests, H.I. (High Impact) Shipboard Machinery, Equipment and Systems, Requirements for
MIL-C-23233 Couplings for Propulsion Units, Auxiliary Turbines and Line Shafts, Naval Shipboard
NAVSEA Technical Publication T9074–AS-GIB-010/271 Requirements for Nondestructive Testing Methods

S2. Ordering Data

S2.1 Classification—Pumps shall be of the following classes:
S2.1.1 Type C-1—Pumps with overhung impellers with all bearings on the driver side of the impeller.
S2.1.2 Type C-2—Close coupled pumps overhung.
S2.1.3 Type C-2(a)—Reference NAVSEA Drawing 803-5773203 “Pump, Fire, 750 to 1000 GPM.”
S2.1.4 Type C-2(b)—Reference NAVSEA Drawing 803-6962399 “Navy Standard Titanium Close Coupled Pump – 6 × 6 × 15.”
S2.1.5 Type C-2(c)—Reference NAVSEA Drawing 803-6962398 “Navy Standard Titanium Close Coupled Pump – 8 × 6 × 11.”
S2.1.6 Type C-2(d)—Reference NAVSEA Drawing 803-6962399 “Pump, Fire, 250 GPM.”
S2.1.7 Type C-2(e)—Reference NAVSEA Drawing 803-7014778 “Commercial/Marine Composite Standard Pump (5-875 GPM)”
S2.1.8 Type C-3—Pumps with impellers between bearings.
S2.1.9 Type C-3(a)—Reference NAVSEA Drawing 803-6397389 “Pump Centrifugal 2000 GPM.”

S2.2 Requirements—All pumps in accordance with this Supplement shall have Fig. S2.1 completed by the purchasing activity. The pump supplier shall use Fig. 1 of this specification when identifying their pump.

S3. Design Requirements

S3.1 Type C-1 and C-2 Pumps:
S3.1.1 The design shall be of the single-stage, single-suction, and volute type.
S3.1.2 Pumps shall have constantly rising head capacity characteristic curves. Pumps with rated capacities of 50 gal/min or more shall have head capacity characteristic curves such that total head at shutoff is not less than 10 % above the head at rated capacity.
S3.1.3 For pumps with closed impellers, wear rings shall be fitted and shall be secured by means of axially oriented setscrews. Pump out vanes can be used instead of back wear rings when approved by the design agency.
S3.1.4 Pump casing joints shall be made up using compressed sheet gaskets or O-rings.

S3.2 Type C-3 Pumps:
S3.2.1 Pumps shall be capable of parallel operation and shall have constantly rising head characteristic curves. Each pump with a total head gage pressure of 100 psig or more shall have a characteristic curve such that at constant rated speed the total head at shutoff will not be less than 10 % nor more than 20 % above total head at rated capacity.
S3.2.2 The preferred design shall be of the single-stage, double-suction, and volute type. Two stages may be used if necessary to provide an acceptable hydraulic design.
S3.2.3 Removable casing wearing rings shall be fitted in all pumps. They shall be designed for anti-rotation. Leakage through the wearing ring clearance shall not impinge directly on the casing.
S3.2.4 Each Type C-3 pump with a total head gage pressure of 100 psig or higher shall have a synthetic rubber seal between the casing wearing ring and casing. The seal may be an O-ring or flat-face type.
S3.2.5 Pump casing joints shall be made up using compressed sheet gaskets. O-rings may be used when approved by the design review agency.
S3.2.6 Suction and discharge connections of split case pumps shall be on the fixed half casing.

S3.3 Casings:
S3.3.1 Casing thickness shall include a minimum 1⁄8-in. allowance for corrosion and core shift.
S3.3.2 Clearance shall be provided around bolt heads and nuts to permit the use of standard tools.

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1 Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111–5098, Attn: NPODS
2 Available from NA VSEA-Mechanicsburg, Code 056, 5450 Carlisle Pike, Mechanicsburg, PA 17055.
S3.3.3 Fitted bolts, dowel pins, or rabbets, or combination thereof, shall be provided to ensure alignment of all fitted parts (upper and lower half pump casings, bearing housings to pump casings, and so forth). Dowel pins shall be corrosion resistant and secured against coming adrift under shock loading.

S3.3.4 Forcing (jacking) bolts shall be provided for ease of joint disassembly.

S3.4 Venting—Pump casing shall be self-venting or be provided with casing vents.

S3.5 Impellers:

S3.5.1 Impellers shall be keyed on the shaft and held securely against axial movement by lock nuts. Other means shall be approved by the design review agency.

S3.5.2 Impellers shall not be furnished with wearing rings. Closed impeller hub wearing surfaces shall have sufficient material thickness to permit reducing the diameter of the impeller hubs as much as 0.050 in. to accommodate undersize casing wearing rings to restore design running clearances.

S3.5.3 Each metal impeller shall be dynamically balanced in accordance with ANSI S2.19, Grade G6.3. Use a density of 0.28 lbm/in.³ to calculate the weight of composite impellers for balancing purposes.

S3.6 Shafts:

S3.6.1 There shall be a maximum shaft deflection of 0.002 in. at stuffing box face calculated at shut-off conditions. Use hydraulic radial load calculation from Hydraulic Institute (ANSI/HI 1.1-1.5-1994), Paragraph 1.3.3.7.2. Impeller weight shall be included in radial load calculation for all horizontal pumps. Shaft sleeves shall not be used for determining stiffness of the pump shaft. For overhung impellers, use the inboard bearing as a cantilever fixed point to calculate shaft deflection. Verify deflection at all other close-running clearance locations.

S3.6.2 Screw threads, except for rolling contact bearing locknuts, shall be opposite to the direction of rotation and can be clockwise or counterclockwise.

S3.6.3 Shaft wearing surfaces (local to bushings, water-lubricated bearings and others), shall be fitted with sleeves. O-rings shall be installed between the shaft sleeves and the shaft.

S3.6.4 Shafts of Type C-2 close-coupled pumps shall be of one-piece construction.

S3.7 Rotating Assembly:

S3.7.1 Rotors shall be dynamically balanced with all rotating parts assembled. For common shaft assemblies, or those using rigid coupling, this requires dynamic balance with the rotating element of the driving unit in place. However, rotating
parts may be balanced individually, provided that, when assembled, the imbalance shall not exceed the limits specified in ANSI S2.19 Grade G6.3.

S3.7.2 Where balancing is required as a maintenance procedure to maintain proper vibration or noise performance of the pump and driver unit in service, the pump shall be designed such that balancing may readily be performed.

S3.7.3 The pump shall be designed to operate at a speed not exceeding 70% of the first critical speed.

S3.8 Mechanical Seals:

S3.8.1 Mechanical seals shall be in accordance with S1 of Specification F 1511 except for Type C-2(a), C-2(d), and C-3(a). Split and cartridge seal designs may be used when approved by the design agency.

S3.8.2 Surface ship seawater pumps with a total head of 30 psig or greater shall be fitted with a cyclone separator at each mechanical seal. The separator shall be rigidly mounted on the pump and shall be connected to the suction and discharged piping by means of tubing and fittings. Other means to clean seal flush water, such as a centrifugal force device, can be used when approved by the design review agency.

S3.8.3 Pumps shall be configured so that normal gland leakage from the mechanical seal shall be collected and piped to waste. The collection area shall be tapped for drain connections so that the leakage can be drained away from the pump casing foundation, bearing housings, and driving units.

S3.8.4 A throttle bushing with close clearance shall be used to prevent excessive leakage in case of mechanical seal failure. The diametrical clearance of the throttle bushing bore shall not be more than 0.025 in. for sleeve diameters up to 2.0 in. For larger diameters, the maximum diametrical clearance shall be 0.025 in. plus 0.005 in. for each additional 1.0 in. of diameter or fraction thereof.

S3.8.5 For C-3-type pumps, split mechanical seals shall be incorporated into the pump design. Split mechanical seals (Grade 3 of Specification F 1511) shall not be used for hydrocarbon service pumps.

S3.8.6 Specification F 1511 and Supplement S1 seals shall use an anti-rotation pin with a 1/8-in. diameter and 1/16-in. protrusion for the mechanical seal stationary element.

S3.8.7 The maximum allowable critical tolerancing required: axial shaft movement maximum of 0.003 in., shaft runout maximum of 0.002-in. TIR at impeller fit area and 0.002-in. TIR at seal area (with seal sleeve removed), impeller wear ring runout maximum of 0.004-in. TIR, seal sleeve runout maximum of 0.004-in. TIR, stuffing box face runout of 0.003-in. TIR per inch of shaft diameter (diameter under the seal sleeve), stuffing box bore diameter runout of 0.005-in. TIR (for piloted gland plate), coupling end shaft runout of 0.002-in. TIR.

S3.9 Couplings:

S3.9.1 For horizontal or vertical four-bearing units, a flexible metal coupling shall be installed between the pump and driver. Flexible couplings for pumps for gasoline pumping service or other explosive/flammable liquids shall be nonsparking. Flexible couplings shall be in accordance with MIL-C-23233, Type II, Class 2.

S3.9.2 Coupling hubs shall be keyed to the shaft end. For pump shaft ends 2.5 in. in diameter or larger, the hubs shall be taper fit, keyed, and secured with lock nuts.

S3.10 Bearings:

S3.10.1 Rolling element bearing life shall be calculated for a basic rating L10 h in accordance with ISO 281 (ANSI/ABMA Standard 9) of at least 25,000 h with continuous operation at rated conditions, and at least 16,000 h at maximum radial and axial loads and rated speed.

S3.10.2 For bearing protection, labyrinth or face seals shall be provided adjacent to the gland for all pumps. The wear life of face seals shall be a minimum of 25,000 h. Motors for close-coupled pumps shall have labyrinth or face seals, or both, installed on the inboard bearing housing. Lip seals are not permitted.

S3.11 Materials:

### TABLE S3.1 Materials

<table>
<thead>
<tr>
<th>Note 1:</th>
<th>316 Stainless</th>
<th>ASTM A 276, A 743/A 743M (CF8M)</th>
<th>Alloy 20</th>
<th>ASTM A 743/A 743M (CN-7M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CD4MCu</td>
<td>ASTM A 890/A 890M (CD4MCu)</td>
<td>Composites</td>
<td>NAVSEA 803-7226047</td>
</tr>
<tr>
<td></td>
<td>Ni Al bronze</td>
<td>ASTM B 148 (C95500, C95800)</td>
<td>Bolts</td>
<td>ASTM A 193/A 193M B8M</td>
</tr>
<tr>
<td></td>
<td>70-30 CuNi</td>
<td>ASTM B 969 (C96400)</td>
<td>Nuts</td>
<td>ASTM A 194/A 194M B8M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classes</th>
<th>I (Freshwater)</th>
<th>II (Seawater/Freshwater)</th>
<th>III (Seawater/Freshwater)</th>
<th>IV (Seawater/Freshwater)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing and pressure Boundary components</td>
<td>316 stainless</td>
<td>Ni Al bronze</td>
<td>CD4Mcu</td>
<td>70-30 CuNi</td>
</tr>
<tr>
<td>Wetted shaft</td>
<td>316 stainless</td>
<td>Monel</td>
<td>Alloy 20</td>
<td>Monel</td>
</tr>
<tr>
<td>Internals</td>
<td>316 stainless CD4Mcu composites</td>
<td>composites</td>
<td>composites</td>
<td>composites</td>
</tr>
<tr>
<td>Mechanical seals</td>
<td>316 stainless alloy 20</td>
<td>Monel</td>
<td>Alloy 20</td>
<td>Monel</td>
</tr>
<tr>
<td>Pressure-containing bolts/studs/nuts</td>
<td>stainless steel</td>
<td>Monel</td>
<td>Alloy 20</td>
<td>Monel</td>
</tr>
</tbody>
</table>

*A Pump/motor hold-down bolts shall be Monel or K-Monel. Carbon steel bolts not permitted because of corrosion.*
S3.11.1 For Type C-2(a), (b), (c), and C-3(a) pumps, all materials shall be in accordance with design drawings. Materials for all other pumps shall be in accordance with Table S3.1. Material classes shown in Table S3.1 shall be followed for all pump components to ensure galvanic compatibility.

S3.11.2 All impellers, wear rings, and shaft sleeves for seawater pumps will use a composite material in accordance with NAVSEA Drawing 803-7226047. Wear rings used in freshwater service pumps shall have a hardness difference then the impeller of at least 50 BHN.

S3.11.3 Proposed alternate materials shall be subject to approval by the design review agency. Components of the pump for which the specific materials are not specified shall use materials best suited for the intended service. Materials, which can be sensitized and subjected to heat treatment in the sensitization range during fabrication, shall not be adversely affected by intergranular corrosion-causing mechanisms. Particular attention shall be given to avoiding sensitization of materials during hard-facing, stress-relieving, or repair-welding operations. Use of cadmium-plated parts, fasteners, and washers is prohibited. Galvanic compatibility between dissimilar metals when used in saltwater applications must be considered.

S3.12 Electric Motors—The pumps shall have non-overloading power characteristics, and the driver-rated horsepower shall at least equal the maximum power requirements of the pump at the rated speed without allowances for a service factor.

S3.13 Hot Freshwater Services (Greater than 200°F condensate/feedwater service):

S3.13.1 NAVSEA detailed review of pump hydraulic test and design data may be used instead of testing at design pump pressures and temperatures.

S3.13.2 Composite internal components are not permitted.

S3.13.3 Vertical pumps shall have mechanical seal chamber vent.

S3.13.4 Single and multi-stage designs are permitted for these services.

S4. Shock and Vibration Testing

S4.1 Shock Test:

S4.1.1 The pump shall undergo a shock test to ascertain that the pump has the necessary shock resistance. The shock test shall be performed in accordance with MIL-S-901, Grade A, and the specific shock test requirements specified in the contract or purchase order. Only one pump of each type, design, and size complete with the driver and all appurtenances and controls shall successfully undergo the shock and vibration qualification at a laboratory or testing facility, which is acceptable to the purchaser. Approvals for shock extensions of similar designs already tested and approved are to be obtained from NAVSEA Philadelphia.

S4.1.2 Before and after shock test, the pump and driver and other components susceptible to internal distortion shall be disassembled to the extent necessary and the critical dimensions and running clearances measured, calculated, and recorded. During this disassembly, the critical components and assemblies subject to shock damage and distortion shall be identified and listed in the inspection record and after completion of the test. The condition of each component and assembly shall be determined and recorded. Shafts, impellers, turbine rotors, motor rotors, and reduction gears shall be inspected by one of the applicable nondestructive test procedures, other than radiography, specified in NAVSEA Technical Publication T9074–AS-GIB-010/271.

S4.1.3 Before and after the shock test, tests in accordance with the Mechanical Soundness and Capacity Test Supplement shall be performed to determine the changes in performance characteristics of the pump. Vibration measurements shall be taken at the bearing caps or housings of the pump and driver at the same speeds during the initial and final capacity test to determine the changes in mechanical operation.

S4.1.4 The unit shall be mounted on the shock machine or barge essentially identical to the actual shipboard installation. The purchasing activity will furnish the contractor a drawing of the shipboard mounting arrangement and foundation’s stiffness. Horizontal pumps, when tested in the inclined position on the medium weight shock machine, shall be oriented so that the direction of shock is perpendicular to the axis of the pump rotation. The pump shall be in operation during the first, third, and fifth blows of the shock test. Pumps with oil lubricated sleeve bearings shall be operated at the minimum speed and pressure required insuring lubrication of bearings and wearing parts. Other pumps shall be operated at the highest rated speed. Pumps shall be operated at as close to the rated condition as possible within the capability of the test facility.

S4.1.5 The pump shall be carefully observed during each shock blow and thoroughly visually examined after each blow. After each blow, the unit shall be operated at as close to maximum rated speed as possible and checked for abnormal noises and vibrations and proper functioning of controls. Turbine driven pumps may be air driven. Tightening of bolts (except for pump/motor hold-down bolts) during shock tests will not be permitted. If any bolt loosens during the test, the equipment manufacturer shall provide a corrective procedure, which must be approved by the purchaser.

S4.1.6 Shock test acceptance criteria shall be as follows:

S4.1.6.1 There shall be no breaking of parts, including mounting bolts.

S4.1.6.2 There shall be no distortion or derangement of any part, which would render the unit incapable of performing as specified.

S4.1.6.3 The amplitude of vibration after test at maximum rated speed shall be less than twice the amplitude measured at the same speed before the test.

S4.1.6.4 Adequate lubrication to all bearings shall be maintained.

S4.1.6.5 Critical dimensions and running clearances shall be maintained.

S4.1.6.6 There shall be no significant change in the head-capacity curve.

S4.1.7 Postshock Test Procedure—The shock-tested unit, if it is to be supplied under a contract or order, shall be restored to the as-new condition by replacement of all parts damaged or distorted beyond the as-new design tolerances. Rolling element bearings shall be replaced regardless of condition. The shock tested rolling contact bearings shall be rendered unusable. The
restored unit shall successfully pass the Hydrostatic Pressure Test Supplement (S5.2.1), the Mechanical Soundness and Capacity Test Supplement (S5.2.4), and the Noise Test Supplement (S5.2.5), if applicable. Quality conformance test documentation shall certify that the unit was subjected to the shock test and subsequently restored, tested, and inspected in accordance with contract requirements. A completed parts examination check list shall be supplied and shall identify the parts which were replaced (such as the bearings) and shall certify that the unit fully conforms to the specifications for unrestricted service.

S4.1.8 Unless otherwise specified by the contract or purchase order, pump units shall be shock tested with its driver. Flexible coupled pumps shock tested with one driver will not be required to be shock tested again when supplied with a different driver of equal or less weight. Drivers are subject to shock tests in accordance with their applicable equipment specifications.

S4.2 Vibration Test:

S4.2.1 The pump shall successfully undergo a vibration test in accordance with the requirements of MIL-STD-167-1, Type I, and as supplemented in the contract or order. The vibration test need not be repeated on subsequent contracts or orders for pumps of identical design to those previously tested, provided the previous tests included the frequencies specified.

S4.2.2 The unit shall be mounted on typical shipboard foundations during the vibration test or the shipboard mounting arrangement shall be simulated in spring mass characteristics except where this mounting arrangement causes the largest test table capacity to be exceeded. Inability to vibration test the unit because of excessive weight or size shall not release the contractor from furnishing equipment which can withstand the specified vibration inputs. Vibration test acceptance criteria shall be in accordance with MIL-STD-167-1, Type I.

S5. Testing Requirements

S5.1 First Article Qualification—One pump of each type, design, and size complete with the driver and all appurtenances and controls shall successfully undergo the specified First Article Qualification at a laboratory or testing facility, which is acceptable to the purchaser. The various first article tests on one pump design may be conducted concurrently, if practical. The tests shall fully establish that the product is reliable and is capable of meeting the specified performance. Design changes which, in the opinion of the purchaser, may adversely affect the applicability of a previously tested and accepted pump design shall be cause to require new design evaluation tests in part or in full. The proposed first article qualification procedures shall be submitted for approval to the purchaser before performing the tests. The design evaluation tests shall consist of the following and are detailed in separate paragraphs: S5.1.1, Performance Test; S5.1.2, Endurance Test; and S5.1.3, Inclined Operation Test. Test reports documenting first article qualification shall be prepared in accordance with accepted engineering practice. The test reports shall document test setup, procedure, significant events, test instruments used including calibration data and accuracy, and measured data. The reports shall be accurate and complete and shall present test results in a professional manner to the purchaser for approval. The report shall include certification of conformance to the specified acceptance criteria that the pump is suitable for its intended application. After approval, test reports shall be distributed as specified in the contract.

S5.1.1 Performance Test:

S5.1.1.1 The performance tests shall be conducted and recorded in accordance with the requirements of the test specified in Mechanical Soundness and Capacity Test Supplement (S5.2.4) except that, in addition, a full-performance map for the rated impeller shall be established. The full-performance map shall be developed by measuring and establishing curves for total head versus capacity, pump efficiency versus capacity, brake horsepower versus capacity, and net positive suction head required versus capacity. For each of those curves, measurements shall be taken at shutoff, rated condition, as close to free delivery as practicable, and at five other capacities approximately evenly spread between these test points. The proposed test procedure for this test shall be submitted to the purchaser for approval approximately at the time of drawing submittal. Test data shall be converted to the specified operating conditions for plotting of all performance curves. The performance curves shall be determined at maximum and minimum operating speed for multispeed pumps. A full net positive suction head (NPSH) curve is required on the lead production unit, and, on subsequent units, the NPSH shall be determined at design rated capacity only.

S5.1.1.2 Acceptance Criteria—The acceptance criteria specified in the Mechanical Soundness and Capacity Test Supplement (S5.2.4) shall be met. The performance map shall exhibit the specified pump performance characteristics. The net positive suction head required shall not exceed the minimum suction head available specified by the contract or order. Controls and safety devices shall function reliably as intended throughout the full operating ranges of capacity and speed.

S5.1.2 Endurance Test:

S5.1.2.1 The pump shall be operated for a period of not less than 500 h of actual running time with a minimum of 60 starts to ascertain reliability of performance and operation. The start/stop cycle requires that the pump be at rest for 5-min minimum before restarting.

S5.1.2.2 Before commencement of the endurance test and immediately after completion of the 500-h operating run, the pump shall be disassembled to the extent necessary and the critical dimensions and running clearance of parts subject to wear, erosion, and derangement shall be measured, calculated, and recorded. Components such as pump impellers and casings subject to erosion, corrosion, cavitation, and wear, the effects of which are not subject to routine measurement, shall be listed in the inspection record and after completion of the test the condition of each component determined and recorded.

S5.1.2.3 During the initial and final hours of the endurance test run, noise, and performance tests (see appropriate paragraphs) shall be performed to determine the changes in pump performance characteristics and noise signature. Vibration measurements shall be taken at the bearing caps or housings of the pump and driver at the same speeds during the initial and final capacity test to determine the changes in mechanical operation.
S5.1.2.4 The endurance test shall not be continuous but shall be interrupted by at least three rest periods of a minimum of 8 h each. The number of starts specified shall be performed at full-line voltage during the course of the test. During an early part of the endurance test, the pump shall be operated continuously for 24 h at a capacity as near free delivery as possible at maximum rated speed and normal specified temperature, submergence, and suction conditions. During the latter part of the endurance test, the pump shall be operated as near shutoff as possible for 12 h continuously. The remainder of the endurance tests shall be run at maximum rated speed and within +20°F, –0°F of maximum specified liquid temperature. The pump shall be operated at one-third, two-thirds, and rated capacity in approximately equal time intervals. Operations at rated capacity shall be at minimum specified net positive suction head available or maximum specified suction lift or vacuum, as applicable.

S5.1.2.5 The pump shall be monitored during the endurance test to record accurately the conditions of operation, the capacity delivered, the total head developed, the speed at which operated, and the general performance observed. Data shall be collected and the pump inspected at least twice per day of operation. For each periodic inspection, in addition to all measured data, the record shall indicate the following:

1. The conditions of the bearings (by audible noise; by feel; and by bearing temperature by means of a probe if the design includes provisions for a probe, otherwise by means of a surface pyrometer on a normally exposed surface; no disassembly required),
2. The airborne noise level (normal-abnormal),
3. The vibration level (normal-abnormal),
4. The smoothness of operation (normal-abnormal),
5. Any other abnormal findings,
6. All adjustments made, and
7. Changes made in the conditions or method of operation.

The Endurance Test acceptance criteria shall be as follows:

1. Head-capacity curve at maximum rated speed after 500 h of pump operation shall conform to the specification requirements and shall show no abnormal deviations from the curve before the 500-h test.
2. Unit performance and operation after 500 h of operation shall be unchanged and normal and meet all specification requirements.
3. Unit operation at the end of the endurance test shall be smooth and shall exhibit noise and vibration levels that are normal and in conformance with the specification. (See 11.6 or MIL-STD-167-1. if S4.2 is invoked.)
4. Lubrication shall have remained satisfactory throughout the test period. Bearing temperatures shall have remained normal and shall be consistent with their respective bearing clearances and oil and grease limitations.
5. Leakage rate from a mechanical shaft seal or pump packing shall have performed as specified. The leakage shall be of a quantity such that it can drain from the pump cavity without overflowing.
6. Running clearances shall be normal.

S5.1.2.6 Postendurance Test Procedures—The unit subjected to the 500-h test, if it is to be supplied under an order or contract, shall be restored to the as-new condition by replacement of all parts worn beyond the as-new design tolerances. The restored unit shall successfully pass the Hydrostatic Pressure Test Supplement, Mechanical Soundness, and Capacity Test Supplement, (S5.2.4.1 (1)), and Noise Tests Supplement (S5.2.5), if applicable. The quality conformance test documentation shall indicate that the unit was subjected to the endurance test and subsequently restored and tested, and that it shall be certified as fully conforming to the specification for unrestricted service.

S5.1.3 Inclined Operation Test—This test shall only be required for pumps with oil lubricated bearings and as a check for oil leakage while inclined at an angle from the normal equal to the combination of the maximum permanent list and trim as specified in the contract or purchase order. Operation in the inclined position shall be as close to rated speed and capacity as practicable. The performance point shall be indicated in the test report.

S5.2 Production Tests—The purchasing activity or its representatives, or both, shall have the right to examine the facilities at the manufacturer’s plant and at his subcontractor’s plants and to witness all tests specified in the contract to the extent specified in the ordering data. Failures, deficiencies, and discrepancies revealed during the performance of the specified tests and the corrective measures taken should be recorded and fully documented in the applicable test records and test reports. After correction of any deficiency, tests shall be repeated to the full extent necessary to determine acceptability for the modified pump. Failures indicative of a design deficiency (as distinguished from shop error or faulty workmanship) shall be reported to the purchaser before a correction is made.

S5.2.1 Hydrostatic Pressure Test—All pressure boundary parts, excluding the mechanical seal, shall be tested hydrostatically to a pressure one and one half times the maximum design working pressure at maximum submergence, but in no case less than 50 psig. The hydrostatic test pressure shall be maintained for at least 30 min or longer as necessary for examination of entire casing.

S5.2.1.1 Acceptance Criteria—The pump shall exhibit no leakage through the pressure boundary material or joints.

S5.2.2 Assembled Pump Pressure Test—The assembled pump shall be tested at a pressure equal to or greater than the sum of the shutoff pressure plus the design suction pressure.

S5.2.2.1 Acceptance Criteria—The pump shall exhibit no leakage from the joint and the pressure boundary. Leakage from the mechanical seal shall be in accordance with Specification F 1511.
S5.2.3 Overspeed Test—Each pump driven by a variable speed driver that can overspeed shall be operated continuously for 30 min at a speed of 25% above maximum design operating speed. The pump need not be under load except as necessary to prevent damage or injury. Continuous shaft and rigid coupled pumps shall be tested with the driver. Units separately driven through flexible couplings and geared units may be tested using a different driver capable of reaching the overspeed condition. The dynamic balance shall be checked using a vibration instrument capable of measuring vibration amplitude of 0.001 in. (peak to peak). Neither the pump nor driver shall exhibit abnormal noises or roughness of operation. Vibration shall not exceed the vibration limits for this equipment in accordance with 11.6 (or MIL-STD-167-1, Type II if S4.2 is invoked).

S5.2.4 Mechanical Soundness and Capacity Test

S5.2.4.1 This test shall be conducted, recorded, and reported in accordance with the Centrifugal Pump Rating Standard and Test Code of the Hydraulic Institute, to the extent that these standards are applicable and are not in conflict with the contract requirements. The test record for each pump shall include the following as a minimum:

(1) Certification of the major pump components (pump, gear assembly, driver) by the manufacturer’s drawing number and serial number that were tested;

(2) Identification of the diameter of the impellers tested in the pump;

(3) A dimensioned sketch of the test loop showing location of the pump, location of all instrumentation, distance (vertical and along the pipe axis) from the suction and discharge gage taps to the pump suction and discharge flanges, vertical distance from the gage(s) to the elevation datum to which they are calibrated, azimuthal location of the gage taps on the pipe circumference, and location and orientation of any elbows in the pump suction piping;

(4) The test loop water temperature during the test;

(5) A list of the test instruments including date of last calibration, advertised accuracy, size, (for example, 0.25 lb/ in.²) of the smallest graduation on the readout scale, range of the readout scale (for example, from 0 to 100 lb/in.²), and unit (for example, lb/in.²) of measurement including the water temperature the gages are calibrated for if a gage is calibrated in feet of water rather than in lb/in.²;

(6) The data sheets of all recorded data, with the unit of measurement identified for all data;

(7) A sample calculation of each type of calculation converting the raw data into specified conditions and showing the conversion in sufficient detail to permit an independent reviewer to verify the calculations, including all temperature and density corrections;

(8) A copy of the specific table of water properties used in the calculations and a reference to the source of that table; and

(9) A plot of the measured head-capacity curve, corrected to the specified operating conditions following the method described in the sample calculations.

S5.2.4.2 The test shall be performed as follows:

(1) Operate the pump and its driver, if motor driven continuously at the rated speed and capacity, with the pumped fluid at ambient temperature until bearing temperatures (not including water-lubricated bearings) stabilize. Stabilization is defined as three consecutively recorded readings taken over intervals of at least 15 min that fall within 3°F band when adjusted for ambient. The three consecutive readings shall not be constantly rising. The pump operation shall be monitored for proper functioning of safety devices, bearing lubrication, and for smooth running.

(a) Acceptance Criteria—Unit operation shall be free of abnormal vibrations and noises. Oil temperature rise in force-feed lubricated bearings shall not exceed 50°F with inlet cooling water to the oil cooler at 85°F. Controls and attached instruments shall function as specified and are in calibration. There shall be no abnormal leakage of water or oil.

(2) Operate the pump at the maximum rated speed with the pumped fluid at maximum normal temperature from recirculation flow to 130% of the rated capacity specified and with the minimum specified suction pressure. The unit shall be operated at shutoff rated condition, 130% of rated capacity and at five other capacities approximately evenly spaced between these points. The unit shall be operated at each test point until the test values being measured stabilize.

(a) Acceptance Criteria—The pump shall deliver the rated capacity, head and efficiency. The head-capacity characteristic curve at maximum rated speed shall satisfy the specified requirements. The total head at all capacities from 0 to 120% of rated capacity on the curve shall not deviate by more than ±5% or –5% of rated head at the corresponding capacity on the head-capacity characteristic curve at maximum rated speed established during initial design testing of the pump. If more than one performance test has been performed for a given pump design for use in a given ship class, then an average of all performance head-capacity characteristic curves established is the one to which the preceding sentence refers. In no case shall the pump deliver less than the rated head at rated flow. The required net positive suction head shall not exceed the minimum net positive suction head available as specified in the contract.

(3) Operate the electric motor-driven unit for a minimum of 1 min in reverse rotation at maximum rated speed.

(a) Acceptance Criteria—The unit shall not be damaged by the reverse rotation test.

S5.2.5 Noise Tests—Airborne and structure-borne noise tests when specified shall be conducted and reported in accordance with MIL-STD-740. Noise test details, instrumentation, and testing techniques identified in MIL-STD-740 shall be submitted to the purchaser before testing for approval. Noise tests shall be performed with the driver furnished with pump, and tests shall be conducted on all units.

S5.2.5.1 Acceptance Criteria—The unit shall meet the noise level limits specified in the contract.
Standard Specification for
Searchlights on Motor Lifeboats

1. Scope

1.1 This specification covers searchlights for motor lifeboats.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification: This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
   B 117 Practice for Operating Salt Spray (Fog) Apparatus

2.2 Military Standard:
   MIL-STD-105D Sampling Procedures and Tables for Inspection by Attributes

3. Descriptions of Terms Specific to This Standard

3.1 lot—a manufacturer’s production run for a specific type of searchlight.

3.2 order batch—size of a specific contract or purchase order taken from the lot.

3.3 production testing—testing performed during a lot run of specific searchlights.

4. Materials and Manufacture

4.1 Material:

4.1.1 All materials used in the construction of these searchlights shall be of a quality suitable for the purpose intended and shall conform to the requirements of this specification.

4.1.2 The searchlight shall be constructed of brass, copper-alloy, an equivalent corrosion-resistant material, or a material that when tested in accordance with Practice B 117 for 200 h, does not show signs of pitting, cracking, or deterioration.

4.1.3 Plastic, when used, shall be of a suitable thermoplastic or thermosetting material so molded as to produce a dense solid structure, uniform in texture, finish, and mechanical properties.

5. Requirements

5.1 The height of the searchlight from the base to the top of the light shall not exceed 19 in. (483 mm).

5.2 The housing of the searchlight shall be capable of free movement of at least 60° above and 45° below the horizontal, and be able to rotate 360° in the horizontal plane. There shall be a means provided to lock the searchlight in any desired position without the use of tools (vertically and horizontally).

5.3 The searchlight shall be capable of illuminating a light colored object at night at 55 ft (180 m). The searchlight shall project a beam of light of not less than 5.5 ft (18 m) in diameter at a distance of 55 ft from the light source. The edge of the beam shall be a point where the intensity of the light is 10% of the maximum intensity. The light source shall have a candlepower rating of no less than 350 000 cd.

5.4 The searchlight shall be capable of being operated for not less than 3 h of continuous use and 6 h of intermittent use.

5.5 The lamp used in the searchlight shall be of the incandescent, quartz, or other type which would allow for instant start. The lamps shall be rated for 12 V.

5.6 Each searchlight shall be watertight. The searchlight shall show no leakage of water following the test method prescribed in 7.1.

5.7 Each searchlight shall be wired with a 6-ft (2-m) length of rubber jacketed hard service flexible cord, unless otherwise specified in 8.3. The conductor size shall be no less than 16 AWG. The cable entry into the searchlight shall be sealed with a watertight bushing and packing gland. A suitable clamping device shall be installed in the area where the cables enter the gland to prevent any force being exerted on the gland or connections. The free end of this cord shall be dead-ended unless otherwise specified in 8.3.
5.8 Each searchlight shall be provided with a handle or handgrip to allow for ease of maneuvering the light into various positions.

6. Workmanship, Finish, and Appearance

6.1 Searchlights shall be of sturdy construction, and free from mechanical, electrical, or other imperfections or defects which materially affect appearance or which may affect quality, reliability, or serviceability.

6.2 The finished searchlight shall not contain rough edges, burrs, or other disfigurements and shall be clean, free from rust, tool marks, and other injurious defects.

7. Test Methods

7.1 Watertightness—The searchlight shall be submerged in a saltwater solution (1.04 sp gr) to a depth of 3 ft (0.9 m) of 60°F (16°C) for 2 h. The light will then be subjected to the tests of 7.2.1 and be in perfect working order.

7.2 Environmental:

7.2.1 Operational Test—The searchlight shall be operated continuously for 3 h at rated voltage in an ambient temperature of 77°F (25°C) and be operational after being subjected to the watertightness test of 7.1. The searchlight shall then be operated intermittently. The intermittent time periods shall be 15 min “ON” and 5 min “OFF” for a total 6-h period. These tests shall be repeated three times.

7.2.2 Impact:

7.2.2.1 Test Conditions—The searchlight shall be placed in a cold chamber at −40 ± 5°F (−40 ± 3°C) for 2 h. With the searchlight stabilized at this temperature, it shall be immediately subjected to the low- and high-impact tests specified in 7.2.2.2 and 7.2.2.3. The point of impact shall be applied to the outside of the case at a point midway between the ends of the case at 4 points 90° apart and the back plate.

7.2.2.2 Low Impact—The searchlight shall be subjected to a 12 in.-lb (1.3 J) impact using a 1-lb (0.5-kg) steel ball at each of the points of impact specified in 7.2.2.1. The searchlight shall then be subjected to the watertightness test (see 7.1). There shall be no evidence of breakage from impact and no evidence of moisture shall be found in the case.

7.2.2.3 High Impact—The searchlight, after passing the low-impact test, shall be again placed in the cold chamber at −40 ± 5°F (−40 ± 3°C) for 2 h and then immediately subjected to a 20 in.-lbf (2.3 J) impact using a 1-lb (0.5-kg) steel ball at each of the points of impact specified in 7.2.2.1. There shall be no evidence of damage to the case or the lens.

7.3 Test for Light Projection—The beam spread of the searchlight shall be shown to meet the calculations contained in the IES Lighting Handbook.2 This test shall be conducted at rated voltage.

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2 IES Lighting Handbook (Vol 1, Section 20), is available from Illuminating Engineering Society of North America, 120 Wall St., New York, NY 10005.
### TABLE 1 Sample Testing

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Standard Practice for
HVAC Duct Shapes; Identification and Description of Design Configuration

This standard is issued under the fixed designation F 1005; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the identification of design configurations and descriptive nomenclature for sheetmetal HVAC ductwork shapes frequently used in shipbuilding. This practice also covers parametric dimensions of these shapes. (See Table 1.)

1.2 This practice does not cover the location of seams or joints within a shape or the method of joining shapes together.

1.3 Since this practice is not measurement sensitive, it is applicable whether inch-pound or SI metric dimensions are used.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Terminology

2.1 Definitions of Terms Specific to This Standard:

2.1.1 branch—portion of a duct system connection to a main duct.

2.1.2 elbow—a fitting used to change direction of air flow.

2.1.3 flat oval—cross section that has flat sides and semi-circular ends.

2.1.4 long axis of flat oval curved so that the flat sides of the flat oval remain in a plane.

2.1.5 offset—fitting that changes the location of the duct with the line of the duct remaining parallel.

2.1.6 ogee—a smoothly curved type of offset. The inside curve of each end is tangent to the outside curve of the other end.

2.1.7 radius corner—cross section that is generally rectangular, but with the corners softened to a radius.

2.1.8 rectangular—rectangular or square cross section.

2.1.9 reducer—a fitting that changes the size but not the cross-section type of duct.

2.1.10 round—circular cross section.

2.1.11 short axis of flat oval—curved so that the flat sides of the flat oval correspond to the curve.

2.1.12 splitter—internal part of some elbows and offsets; sometimes required in diverging transitions. Used to provide more uniform velocity and distribution of air flow. The number and location of splitters is determined by calculation or from a nomograph.

2.1.13 straight—duct that remains constant in cross section and size throughout its length.

2.1.14 throat—wrapper around the inside of a fitting.

2.1.15 transition—fitting that changes the cross-section type of the duct.

2.1.16 vane—internal part of vaned turns. Used to provide more uniform velocity of air flow. Configuration, number, and location of vanes is determined from drawing, NAVSHIPS No. S3801-385260. The direction of airflow must be marked on vaned turns.

2.1.17 vaned turn—a fitting containing vanes that is used to change the direction of air flow.

2.2 Variables Specific to This Standard:

A—Angle. Included angle of an elbow, branch, vaned turn, or slant-top fitting.

AF—Air In indicates the length of the straight portion of a vaned turn in the “air in-flow” side.

AO—Air Out indicates the length of the straight portion of a vaned turn on the “air out-flow” side.

B—Distance from the intersection of the center lines of a branch and the main duct to the end of the main duct.

CY—Distance between centers of a Y branch.

D—Depth of a part.

DB—Depth of a branch.

DIA—Diameter of a part.

DIAB—Diameter of a branch.

DIA1—Major diameter of a part.

DIA2—Minor diameter of a part.

DI—Major depth of a part.

D2—Minor depth of a part.

F—Flat section that softens the corner of a vaned turn.

This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery.


TABLE 1 HVAC Standard Nomenclature and Numbering System

1. Straight:
   1.1 Straight-round
   1.2 Straight-flat oval
   1.3 Straight-rectangular

2. Offset:
   2.1 Offset-round
   2.1.1 Offset-flat oval-long axis
   2.2 Offset-flat oval-short axis
   2.3 Offset-rectangular-without splitters
   2.3.1 Offset-rectangular-with splitters
   2.4 Offset-ogee-without splitters
   2.4.1 Offset-ogee-with splitters
   2.5 Offset-rectangular-reducing-without splitters
   2.5.2 Offset-rectangular-reducing-with splitters

3. Elbow:
   3.1 Elbow-round
   3.2 Elbow-flat oval-long axis
   3.2.1 Elbow-flat oval-short axis
   3.3 Elbow-rectangular-without splitters
   3.3.1 Elbow-rectangular-with splitters
   3.4 Elbow-rectangular-reducing-without splitters
   3.4.2 Elbow-rectangular-reducing-with splitters
   3.5 Elbow-rectangular-transition-without splitters
   3.5.2 Elbow-rectangular-transition-with splitters

4. Vaned Turn:
   4.1 Vaned turn

5. Reducer:
   5.1 Reducer-round
   5.2 Reducer-flat oval
   5.3 Reducer-rectangular

6. Transition and Bellmouth:
   6.1 Transition-flat oval to round
   6.2 Transition-rectangular to round
   6.3 Transition-rectangular to flat oval
   6.4 Transition-rectangular to radius corner
   6.5 Transition-radius corner to flat oval
   6.6.1 Bellmouth-round
   6.6.2 Bellmouth-rectangular

7. Branch:
   7.1.1 Branch-round-on equal diameter round
   7.1.2 Branch-round-on larger diameter round
   7.1.3 Branch-round-on round reducer
   7.1.4 Branch-round-on rectangular straight
   7.1.5 Branch-round-on rectangular reducer
   7.1.6 Branch-round “Y”
   7.1.7 Branch-rectangular to round-“Y”
   7.2.1 Branch-rectangular-on rectangular straight
   7.2.2 Branch-rectangular-on rectangular reducer

---

$L$—Length of a part.
$LB$—Length of a branch from the end of the branch to the point where the centerline of the branch intersects the centerline of the main duct.
1.1—Major length of a Y branch.
1.2—Minor length of a Y branch.
$O$—Offset in one direction.
$R$—Radius of a bellmouth.
$RC$—Radius corner.
$RV1$—Radius of first splitter at V extension.
$RV2$—Radius of second splitter at V extension.
$RV3$—Radius of third splitter at V extension.
$RZ1$—Radius of first splitter at Z extension.
$RZ2$—Radius of second splitter at Z extension.
$RZ3$—Radius of third splitter at Z extension.
$RI$—Radius of first splitter.
$R2$—Radius of second splitter.
$R3$—Radius of third splitter.
$S1$—Distance of first splitter from the outside curve of an ogee offset.
$S2$—Distance of second splitter from the outside curve of an ogee offset.
$S3$—Distance of third splitter from the outside curve of an ogee offset.
$TR$—Throat radius is the radius of the inside surface of an elbow or offset. Normally TR is equal to the width (of a rectangular elbow).
$TR1$—Major throat radius of a reducing offset.
$TR2$—Minor throat radius of a reducing offset.
$V$—Extension on one end of a part, opposite from Z.
$W$—Width of a part.
$WB$—Width of a branch.
3. Significance and Use

3.1 Standard nomenclature shall be used to facilitate communication between designers, suppliers, and users of HVAC ventilation ductwork components.

3.2 Standard design parameters shall be used to define ventilation ductwork shapes.

3.3 Standard variables for design parameters (see 2.2) are useful in writing CAD/CAM software for automatic fabrication of ventilation ductwork shapes.

4. Description of HVAC Standard Shapes

4.1 The HVAC standard shapes covered by this practice are described by Figs. 1-41. The shapes have been divided into seven categories by function.

4.1.1 HVAC Duct Categories:

4.1.1.1 Straight.

4.1.1.2 Offset.

4.1.1.3 Elbow.

4.1.1.4 Vaned turn.

4.1.1.5 Reducer.

4.1.1.6 Transition and bellmouth.

4.1.1.7 Branch.

4.1.2 Each sketch is identified by the standard name and indicates the design parameters needed for fabrication.

4.2 The HVAC standard shapes are also identified by number for convenient reference. A modified decimal numbering system is used for this purpose.

4.2.1 Primary Number—The primary numbers 1 through 7 correspond to the seven categories of shapes.

4.2.2 Secondary Number—The secondary number designates a predominant characteristic, such as cross section that differentiates a shape from other shapes in the category.

4.2.3 Ternary Number—The ternary number, when required, is used when further differentiation is required. A summary of this system is presented in Table 1.

5. Keywords

5.1 air conditioning; heating; HVAC duct configuration; HVAC ducts; HVAC duct shapes; ventilation
FIG. 3  Shape 1.3—Straight-Rectangular

FIG. 4  Shape 2.1—Offset-Round
FIG. 5  Shape 2.2.1—Offset-Flat Oval-Long Axis

FIG. 6  Shape 2.2.2—Offset-Flat Oval-Short Axis
FIG. 7 Shape 2.3.1—Offset-Rectangular-Without Splitters

FIG. 8 Shape 2.3.2—Offset-Rectangular-With Splitters
FIG. 9  Shape 2.4.1—Offset-Ogee-Without Splitters

FIG. 10  Shape 2.4.2—Offset-Ogee With Splitters
FIG. 11  Shape 2.5.1—Offset-Rectangular Reducing-Without Splitters

FIG. 12  Shape 2.5.2—Offset-Rectangular Reducing-With Splitters
FIG. 13 Shape 3.1—Elbow-Round

FIG. 14 Shape 2.1—Elbow-Flat Oval-Long Axis

FIG. 15 Shape 2.2—Elbow-Flat Oval-Short Axis

FIG. 16 Shape 3.1—Elbow-Rectangular-Without Splitters

FIG. 17 Shape 3.2—Elbow-Rectangular-With Splitters
FIG. 18 Shape 3.4.1—Elbow-Rectangular Reducing-Without Splitters

FIG. 19 Shape 3.4.2—Elbow-Rectangular Reducing-With Splitters

FIG. 20 Shape 3.5.1—Elbow-Rectangular Transition-Without Splitters
FIG. 21  Shape 3.5.2—Elbow-Rectangular Transition-With Splitters

FIG. 22  Shape 4.1—Vaned Turn

Note 1—Detail of vane fabrication and installation given by drawing, NAVSHIPS No. S3801-385260.
FIG. 23  Shape 5.1—Reducer-Round

FIG. 24  Shape 5.2—Reducer-Flat Oval
FIG. 25  Shape 5.3—Reducer-Rectangular

FIG. 26  Shape 6.1—Transition-Flat Oval to Round
**FIG. 27** Shape 6.2—Transition-Rectangular to Round

**FIG. 28** Shape 6.3—Transition-Rectangular to Flat Oval
FIG. 29 Shape 6.4—Transition-Rectangular to Radius Corner

FIG. 30 Shape 6.5—Transition-Round Corner to Flat Oval

FIG. 31 Shape 6.6.1—Bellmouth-Round

FIG. 32 Shape 6.6.2—Bellmouth-Rectangular

FIG. 33 Shape 7.1.1—Branch-Round-On Equal Diameter Round
FIG. 34 Shape 7.1.2—Branch-Round-On Larger Diameter Round

FIG. 35 Shape 7.1.3—Branch-Round-On Round Reducer
FIG. 36  Shape 7.1.4—Branch-Round-On Rectangular Straight

FIG. 37  Shape 7.1.5—Branch-Round-On Rectangular Reducer
Note 1—V extensions may be added to the branches.

FIG. 38 Shape 7.1.6—Branch-Round-“Y”

Note 1—V extensions may be added to the branches.

FIG. 39 Shape 7.1.7—Branch-Rectangular to Round “Y”
FIG. 40  Shape 7.2.1—Branch-Rectangular-On Rectangular Straight

FIG. 41  Shape 7.2.2—Branch-Rectangular-On Rectangular Reducer
Standard Specification for
Entrainment Separators for Use in Marine Piping
Applications

This standard is issued under the fixed designation F 1006; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the minimum requirements for
the pressure-temperature rating, testing, and making of
pressure-containing vessels for entrainment separators.

1.2 The values stated in inch-pound units are to be regarded
as the standard. The values given in parentheses are for
information only.

1.3 The following safety hazards caveat pertains only to the
test methods portion, Section 6, of this specification: This
standard does not purport to address all of the safety concerns,
if any, associated with its use. It is the responsibility of the user
of this standard to establish appropriate safety and health
practices and determine the applicability of regulatory limita-
tions prior to use.

2. Referenced Documents

2.1 ANSI Standards:
B2.1 Pipe Threads (Except Dryseal)
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable Iron Threaded Fittings, Class 150 and 300
B16.4 Cast Iron Threaded Fittings, Class 125 and 250
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings, Socket Welding and Threaded
B16.15 Cast Bronze Threaded Fittings, Class 150 and 300
B16.24 Bronze Flanges and Flanged Fittings, Class 150 and
300
B16.25 Buttwelding Ends
B16.31 Nonferrous Pipe Flanges

2.2 ASME Standards:
SA278 Cast Gray Iron Pressure Vessels
SA395-60 Cast Ductile Iron
Boiler and Pressure Vessel Code, Section VIII
Boiler and Pressure Vessel Code, Section II

3. Definitions of Terms Specific to This Standard

3.1 entrainment separator—a mechanical device inserted in
a pipeline which by centrifugal force, baffles, or other means
will separate a liquid from a gas (vapor).

3.2 hydrostatic test—the act of filling an entrainment sepa-
rat or vessel with water and applying internal pressure to all
parts of the vessel.

3.3 master gage—the calibrated gage used to verify the
accuracy of the test gage. This gage shall be recalibrated
traceable to the National Bureau of Standards.

3.4 pressure rating—the maximum working pressure of an
entrainment separator when operated at a specific temperature.

3.5 proof test—the act of filling an entrainment separator
vessel with water and applying internal pressure to all parts of
the vessel for the purpose of causing yielding of the vessel and
bursting of the vessel.

3.6 temperature ratings—minimum and maximum tem-
peratures at which the entrainment separator may be operated
while at specific pressures.

3.7 test gage—the pressure gage that is used to check the
internal pressure of the entrainment separator. The test gage
shall be calibrated at least annually or at any time it is
suspected to be in error by a calibrated master gage.

4. Materials and Manufacture

4.1 The pressure-temperature ratings established under this
specification are based upon the manufacturer’s usage of high
quality materials produced under regular control of chemical
and physical properties by a recognized process. The manu-
ufacturer shall be prepared to submit certification of compliance,
verifying that his product has been so produced and that it has been manufactured from material with chemical and physical properties at least equal to the requirements of the appropriate standard or specification listed in 4.3 of this specification or Section II of the ASME Boiler and Pressure Vessel Code.

5.2 The design pressure-temperature of entrainment separators covered in this specification will be established by the manufacturer using one of the following methods:

5.2.1 Design calculations in accordance with the requirements prescribed in the ASME Boiler and Pressure Vessel Code, Division VIII, Section VIII, Division 1, Part UG of Subsection A and the applicable part of Subsection C.

5.2.2 Proof test in accordance with the requirements of UG 101 (m), UCI-101, or UCD-101 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.2.3 Where any part of the entrainment separator vessel cannot be designed within the scope of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.2.3.1 The hydrostatic test pressure shall be applied gradually to the entrainment separator and held stationary at each increment for a sufficient time in order that a visual inspection can be made for leaks or deformation of the vessel. The final value of hydrostatic test pressure that is not in conflict with 5.2.3.2 is called \( P_{HT} \).


6. Test Methods

6.1 All entrainment separators must be pressure tested in accordance with the following:

6.1.1 Each entrainment separator shall be tested by subjecting it to an internal hydrostatic test procedure, which at every point in the separator is at least equal to 1.5 times the maximum allowable working pressure, multiplied by the lowest ratio of the stress value for the design temperature.

\[
P = \frac{P_{HT}}{4} \times \left( \frac{S_1}{S_2} \right) \quad \text{(for steel vessels)}
\]

\[
P = \frac{P_{HT}}{4} \times \left( \frac{T_1}{T_2} \right) \quad \text{(for cast iron vessels)}
\]

where:

- \( P \) = maximum allowable working pressure (psig) at design temperature,
- \( P_{HT} \) = hydrostatic test pressure (psig) at test temperature,
- \( S_1 \) = stress value at design temperature (psi),
- \( S_2 \) = stress value at test temperature (psi),
- \( T_1 \) = specified minimum tensile strength (psi), and
- \( T_2 \) = actual tensile strength test specimen (psi).

5.2.3.1 Stress values \( S_1 \) and \( S_2 \) are determined from Section VIII, of the ASME Boiler and Pressure Vessel Code.

5.2.3.2 The value of \( P_{HT} \) to be used in determining the maximum allowable working pressure shall be the maximum pressure to which the entrainment separator was subjected to without permanent deformation or rupture.

5.2.3.3 Test water temperature\(^6\) and entrainment separator temperature must be at equilibrium before hydrostatic test pressure is applied.

5.2.3.4 All possible air pockets must be purged while the entrainment separator vessel is being filled with water. Adequate vents shall be provided at all high points of the vessel.

5.2.3.5 External equipment not to be pressurized with the entrainment separator should be isolated or disconnected before applying the hydrostatic test pressure.

5.2.3.6 Hydrostatic test pressure shall be applied gradually to the entrainment separator and held stationary at each increment for a sufficient time in order that a visual inspection can be made for leaks or deformation of the vessel. The final value of hydrostatic test pressure that is not in conflict with 5.2.3.2 is called \( P_{HT} \).

6.1.1.1 The hydrostatic test pressure shall be held stationary for a suitable time necessary for observation and inspection of the separator. The minimum time of test shall be no less than 1 min.

6.1.1.2 A test gage, as defined in this specification (see Section 3) shall be connected directly to the entrainment separator.

6.1.1.3 For compliance with ASME Codes leading to ASME certification, proceed with steps as outlined in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code for Standard Hydrostatic Tests.

7. Packaging and Package Marking

7.1 Each entrainment separator shall have a securely attached nameplate or other permanent marking indicating the following:

7.1.1 Manufacturer’s name and trademark,
7.1.2 Pressure-temperature rating,

\(^6\) Test water temperature to be no less than 60°F (10°C), but not to exceed 125°F (52°C).
7.1.3 Manufacturer’s serial number,  
7.1.4 Year built,  
7.1.5 Size (end connection pipe size),  
7.1.6 Flow direction,  
7.1.7 National board number, where applicable,  
7.1.8 ASME code stamp, where applicable, and  
7.1.9 ASTM designation and year of issue.

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Standard Specification for Pipeline Expansion Joints of the Packed Slip Type for Marine Application

1. Scope

1.1 This specification covers the design, manufacturing, and testing of packed slip-type expansion joints used in pipelines for accommodating axial thermal growth or contraction from the pipeline carrying fluid.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service


B 650 Specification for Electrodeposited Engineering Chromium Coatings on Ferrous Substrates

2.2 ANSI Standards:

B16.5 Steel Pipe Flanges and Flanged Fittings

B16.25 Buttwelding Ends

2.3 ASME Standards:

Section V Nondestructive Examination

Section VIII, Division 1 Pressure Vessels

Section IX Welding and Brazing Qualifications

2.4 AISI Standard:

C-1018 Carbon Steel

3. Classification

3.1 The expansion joints shall be of the following types, styles, classes, and forms:

3.1.1 Type I—Injectable semiplastic packing type, designed for injecting packing under full-line pressure.

3.1.2 Style I—Internally externally guided with guides integral with stuffing box.

3.1.3 Style II—Internally externally guided with guides integral with stuffing box and with low-friction inserts at the guide surfaces.

3.1.4 Class I—Single joint, single slip.

3.1.5 Class II—Double joint, double slip.

3.1.6 Form I—Weld end.

3.1.7 Form II—Flanged end.

3.1.8 Form III—Other.

4. Ordering Information

4.1 Expansion joints shall meet all the requirements of the latest issue of this specification. Where possible, the expansion joint shall be the manufacturer’s standard commercial product. Additional or superior features that are not prohibited by this specification but which are a part of the manufacturer’s standard product, shall be included with the expansion joint being offered. A standard commercial product is a product that has been sold or is currently being offered for sale on the commercial market through advertisements or manufacturer’s catalogs, or brochures, and represents the latest production model.

4.2 Purchase order or inquiry for expansion joints to this specification shall specify the following:

4.2.1 Title, number, and latest revision of this specification.

4.2.2 Style, class, and form required.

4.2.3 Materials, other than standard as specified (see Section 8).

4.2.4 Service conditions shall specify the following:

4.2.4.1 Maximum and minimum operating temperature (°F).

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Notes:

1 This specification is under the jurisdiction of Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


2 Annual Book of ASTM Standards, Vol. 01.01.

3 Annual Book of ASTM Standards, Vol. 01.02.

4 Annual Book of ASTM Standards, Vol. 01.04.

5 Annual Book of ASTM Standards, Vol. 02.05.


7 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

8 Available from American Iron and Steel Institute (AISI), 1101 17th St., NW, Suite 1300, Washington, DC 20036.
4.2.4.2 Maximum operating pressure (psig).
4.2.4.3 Fluid handled.
4.2.4.4 Corrosive conditions, if applicable.
4.2.5 Total axial expansion or contraction.
4.2.6 ANSI pressure class, facing, and drilling for flanged end joint and pipe schedule or wall thickness of ends for weld end joint.
4.2.7 If base is required for support or main anchor on Class I expansion joint.
4.2.8 Drain connection, if required.
4.2.9 Service connection if required, noting location and type of connection.
4.2.10 Slip protectors, if required.
4.2.11 Adjustment rods for field extension or compression of the slip if required.
4.2.12 If hot-dip galvanizing of parts is required.
4.2.13 Spare parts, accessories, and special tools, if required.
4.2.14 Hydrostatic testing and test pressure, if required.
4.2.15 Radiographic or other nondestructive testing of weld joints if required.

5. Materials and Manufacture

5.1 Materials:
5.1.1 Materials of construction shall conform to the requirements as specified in this specification (see Section 8) and shall be new and free from defects that would adversely affect the performance of individual components or assemblies.
5.1.2 As specified in this specification and as required, the expansion joint shall be provided with flanged or welded end connections, limit stops, stuffing boxes with integral guides, base, drain connection, service connection, slip protectors, and adjustment rods.

5.2 Manufacture:
5.2.1 General—Unless otherwise required by this specification, the manufacturer’s standard shop practices for the fabrication of the expansion joint are acceptable, provided these practices conform to the requirements and recommendations of this specification.
5.2.2 All Welding—Welding procedure qualifications, welder performance qualification, welding materials, preheat, and postweld heat treatment if required, shall be in accordance with ANSI B31.1 and ASME Code Section IX.
5.2.3 Identification—Each completed expansion joint shall have a name plate made from a corrosion-resistant material permanently attached showing as a minimum the following:
5.2.3.1 Manufacturer’s model number and joint size,
5.2.3.2 Design pressure and design temperature range,
5.2.3.3 Nominal traverse or movement per slip,
5.2.3.4 Type of packing and service fluid, and
5.2.3.5 Date of manufacture.

6. Joint Descriptions

6.1 Styles:
6.1.1 Style I—The slip of the expansion joint shall be guided with the body of the expansion joint by internal and external guides that are integral with the stuffing box. Semiplastic packing shall be injected into the stuffing box and may be contained within the stuffing box chamber by ring-type pack-

ing. All packing shall be of the self-lubricating type. The expansion joint and semiplastic packing shall be suitable for the safe injection of the packing under full-line pressure to stop leakage. Provisions for packing injection shall be by devices located radially about the stuffing box and designed to permit a maximum evacuation of packing at the bottom of the packing device when the injector is fully engaged. The number of devices with injectors for each stuffing box shall be in accordance with the manufacturer’s standard practice. The design of the packing injection devices shall be such as to ensure no blowback of injectable packing or the service fluid when injecting packing under full-line pressure.
6.1.2 Style II—The expansion joint shall be the same as Style I except low-friction corrosion-resistant material or inserts shall be used for internal and external guiding to prevent slip scoring from pipe misalignment or vibration and to prevent corrosion of the guide surfaces.
6.1.3 Form I—Welded End: The expansion joint shall have provisions at each end of the joint for field welding to the adjoining pipe line.
6.1.4 Form II—Flanged End: The expansion joint shall have flanges at each end of the joint for bolting to the mating flanges of the adjoining pipe line.
6.1.5 Form III—The expansion joint shall have other end connections as specified for attaching to the adjoining pipe line.

7. Design

7.1 The expansion joint shall be designed to conform to applicable sections of the latest edition of ANSI B31.1 and other applicable documents as noted in Section 2.
7.2 Compression Force—Unless otherwise specified, the force to compress or extend the slip of the expansion joint shall not exceed 1000 lbf/in. (175 100 N/m) of nominal pipe diameter.

8. Construction

8.1 Slip—The slip shall be manufactured from steel pipe conforming to Specification A 53/A 53M, Grade B, or a rolled and welded cylinder from Specification A 285/A 285M, Grade C plate, or equal with the longitudinal weld seam 100 % radiographed. The minimal wall thickness of the pipe or rolled cylinder shall be equivalent to Schematic 80 pipe for all sizes to 14 in. (356 mm), inclusive and Schematic 60 for sizes 16 to 24 in. (406 to 610 mm) to preclude slip collapse as a result of external loading of the injectable packing. Heavier wall pipe may be required for expansion joints subjected to pressures above 600 psig and for pipe sizes above 24-in. (610-mm) diameter.
8.1.1 Chrome Plate—The slip of the expansion joints shall be chrome plated with engineering chrome in accordance with Specification B 650, Class 50.
8.2 Stuffing Box—The stuffing box with integral internal and external guides shall be machined from Specification A 53/A 53M, Grade B Pipe, or AISI C-1018 seamless tubing or cast steel in accordance with A 216/A 216M, Grade WCB. A rolled and welded cylinder from Specification A 285/A 285M, Grade C plate, or equal may be used provided the longitudinal weld seam is 100% radiograph examined in accordance with ANSI B31.1 and ASME Code Section V.

8.3 Traverse Chamber—This chamber, also referred to as the “E.J. Body,” shall be machined from Specification A 53/A 53M, Grade B seamless steel pipe having a wall thickness suitable for the design service conditions. A rolled and welded cylinder from Specification A 285/A 285M, Grade C, or equal steel plate of suitable thickness for the design service conditions may also be used if the longitudinal weld seam is 100% radiograph inspected to ANSI B31.1 and ASME Code Section V.

8.4 End Connections—The end connections of the expansion joint (see Section 6) shall be flanged, weld end, combination of both, or others as specified. Flanges shall conform to ANSI B16.5 and be of the size, material, pressure class, and facing specified. Weld ends shall be beveled for welding to ANSI B16.5 and be of the size, material, pressure class, and nation of both, or others as specified. Flanges shall conform to ANSI B31.1 and ASME Code Section V.

8.4.1 Body End Connection for Class I Expansion Joints:
8.4.1.1 Form I—Weld End: The reduction of the body size to the pipeline size shall be accomplished by a formed reduction of the traverse chamber (body) or by a reducer butt welded to the traverse chamber (body) that meets the requirements of ANSI B31.1 and the ASME Code Section VIII, Division 1.

8.4.1.2 Form II—Flanged End: Forged flanges shall be attached to the body by butt welding only and shall be in accordance with the requirements of ANSI B31.1 and the ASME Code Section VIII, Division 1.

8.5 Limit Stops—Limit stops may be of the external or internal type manufactured from a suitable material and designed to withstand the full-line pressure thrust load in the event of a pipeline anchor failure.

8.6 Internal and External Guides—See 8.2.

8.6.1 Low-Friction Internal and External Guides—The low-friction internal and external guides or inserts shall be made from noncorrosive materials with appropriate differential hardness to also prevent scoring or binding of the slip.

8.7 Base:

8.7.1 Expansion Joint Without a Service Connection—When a base is specified for Class I expansion joints, the base shall be designed for use as a main anchor. Class II expansion joints shall have a base that is suitable as an intermediate anchor. The base shall be of cast or fabricated steel that conforms to the applicable ASTM standard and shall be suitably attached to the joint and drilled in accordance with the manufacturer’s standard practice.

8.7.2 Expansion Joint With a Service Connection—Class I and Class II expansion joints with a service connection shall be provided with a main anchor base and all anchor loading data (forces and moments) shall be made available to the manufacturer to assure adequate anchor design. The base shall be of cast or fabricated steel that conforms to the applicable ASTM standard and shall be suitably attached to the joint and drilled in accordance with the manufacturer’s standard practice.

8.8 Service Connection—Unless otherwise specified, a service connection, when required, shall be the manufacturer’s standard design and shall meet the applicable requirements of the ASTM, ANSI, and ASME Codes. The service connection shall be supplied with end connections as specified (see 8.5).

8.9 Drain Connection—When required, a drain connection shall be attached to the body of the expansion joint and shall be the manufacturer’s standard unless otherwise specified. The drain connection shall meet the requirements for fitting connections as specified in ANSI B31.1.

8.10 Packing—Unless otherwise specified, the packing shall be the manufacturer’s standard-type packing and shall be suitable for the specified service conditions.

8.11 Other Materials of Construction—Where the expansion joint is to transfer corrosive fluids, or be installed in a corrosive atmosphere, corrosive-resistant materials as specified may be substituted for the carbon steel components, especially the sliding slip.

9. Drawing Requirements

9.1 Drawings—When specified, dimensional sketches or drawings sufficiently detailed to describe the expansion joint to be supplied, shall be submitted with bid proposals. The inch-pound system of measurements shall be used to dimension drawings. Drawings shall note that the design of the components or products is in full compliance with this specification.

10. Cleaning and Surface Preservation

10.1 Cleaning—The internal and external surfaces of the expansion joint shall be cleaned of dirt, oil, grease, and other foreign material using a suitable cleaning solvent. Extreme care shall be used to ensure the interior is free of any slag, steel chips, or other similar materials that could lodge between the slip and the body and score the slip surface.

10.2 Surface Preservation—Unless specified, no preservation will be required on the internal surface of the expansion joint. All external surfaces except the chrome-plated slip surface, flanged faces, and weld bevel surfaces shall be painted in accordance with the manufacturer’s standard practice. Weld end joint surfaces for field welding shall be coated with “deoxaluminate” preservative.

11. Packaging and Package Marking

11.1 All openings shall be suitably sealed to protect the opening connection surfaces and prevent entrance of foreign materials.

11.2 Unless otherwise specified, the exposed chrome-plated surface of the slips shall be protected in accordance with the manufacturer’s standard practice.

11.3 Unless otherwise specified, the completed expansion joints shall be suitably attached with steel strapping or hold down bolting to wood skids or crates in accordance with standard commercial practice for domestic shipments.
12. Quality Assurance

12.1 Inspection—Unless otherwise specified, the contractor shall perform inspections as required to assure compliance with this specification. The procuring agency may establish inspection requirements, and it is the contractor’s responsibility to provide access to his facilities for the procuring agency’s inspection of material, work in process, and quality assurance testing or results as required.

12.2 Material Certification—Certified material test reports or certificates of compliance shall be required for all pressure-retaining material. To maintain traceability, all pressure-retaining material shall be metal stamped or otherwise suitably marked with heat treat numbers or other identification codes. If metal stamping is used, the indentations shall not exceed 1/32 in. (0.8 mm) or infringe on minimum wall thickness. A round-nose, low-impression-type stamping die shall be used.

12.3 Nondestructive Testing—When required, all nondestructive testing shall be performed by qualified personnel in accordance with qualified acceptable procedures.

12.3.1 Radiography—Radiographic examination of welds shall be in accordance with ANSI B31.1 and Section V of the ASME Code.

12.3.2 Visual Examination, Magnetic Particle, and Liquid Penetrant Examination—Whenever required, these examinations shall be in accordance with ANSI B31.1 and Section V of the ASME Code.

13. Keywords

13.1 axial thermal growth; expansion joint; fluid pipeline; marine technology; packed slip expansion joint; pipeline; ship
Standard Specification for Flashlights on Vessels

This standard is issued under the fixed designation F 1014; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope
1.1 This specification covers three types of flashlights (see Section 4).
1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.
1.3 The following precautionary caveat pertains only to the test method portion, Section 9, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents
2.1 Military Standard:
MIL-STD-105D Department of Defense Standard; Sampling Procedures and Tables for Inspection by Attributes
2.2 UL Standard:
UL Standard No. 783

3. Terminology
3.1 Definitions of Terms Specific to This Standard:
3.1.1 lot—a manufacturer's production run for a specific type of flashlight.
3.1.2 order batch—the size of a specific contract or purchase order taken from the lot.
3.1.3 production testing—the testing performed during a lot run of specific flashlights.

4. Classification
4.1 The three types of flashlights covered in this specification are classified as follows:

4.1.1 Type I—Flashlights for use in lifeboats and liferafts.
4.1.2 Type II—Flashlights for use in hazardous locations where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.
4.1.3 Type III—Flashlights for use in lifeboats and liferafts and suitable for hazardous locations.

4.2 Type I flashlights shall be manufactured in accordance with Sections 2-11. Type II flashlights shall meet the requirements in Sections 11 and 12. Type III flashlights shall meet the requirements in Sections 2-12.

5. Materials and Manufacture
5.1 Materials—All materials used in the construction of these flashlights shall be of a quality suitable for the purpose intended and shall conform to the requirements of this specification.
5.2 Manufacture—Plastic, when used, shall be a suitable thermoplastic or thermosetting material so molded as to produce a dense solid structure, uniform in texture, finish, and mechanical properties.

6. General Requirements
6.1 Each flashlight shall be a three-cell light.
6.2 Each flashlight shall provide a concentrated beam of light. When used in this specification, a concentrated beam of light is light projected in a nearly parallel beam and is used to illuminate objects at considerable distances.
6.3 The flashlight shall show no leakage of water and shall be in perfect working order following the test prescribed in 9.2.
6.4 The proportions and design of each flashlight shall be such that the assembled unit complete with lamp and cells shall be capable of withstanding, without breakage or material distortion of any part and without upsetting the lamp focus, the test specified in 9.6. Damage of lamp filament or shifting of filament within the lamp as a result of this test shall not be cause for rejection of the flashlight if the flashlight operates when the spare lamp is used.
6.5 Each flashlight must be furnished with two lamps. One of these lamps is a spare and must be contained within the body of the flashlight, either in the end cap or reflector head area.
6.6 All metal parts of each flashlight shall be made of corrosion-resistant material. All copper or copper-alloy parts coming in contact with rubber shall not corrode or disintegrate the rubber.

6.7 The construction of each flashlight shall be such that a metallic contact outside the case cannot close the battery circuit and cause the light to come on.

6.8 Each flashlight shall be provided with means to prevent it from rolling.

7. Physical Requirements

7.1 Dimensions—Each flashlight shall not exceed 11½ in. (292 mm) in length and shall have a lens ring diameter of no more than 2½ in. (63.5 mm).

7.2 Case, Lens Head Ring, and End Cap:

7.2.1 The flashlight case must be suitable to receive three commercial D-size dry cells. The exterior of the flashlight shall have molded flutes or ribs to provide a satisfactory gripping surface when wet. Cells must be held in the case under sufficient pressure to ensure good contact and to prevent breaking of the circuit when the flashlight is tested in accordance with 9.1.2. The flashlight must be constructed so that the cells are readily replaceable.

7.2.2 The case, ring, and cap, need not be made of the same material but cooperating threaded surfaces should be of the same type material.

7.3 Lens—The lens shall be of good quality, laminated, shatter-proof glass or clear plastic, free from bubbles, striae, wrinkles, or other defects and blemishes that would affect the light distribution. The lens shall be secured to the lens head ring by a suitable retaining ring or other device so as to prevent it from being dropped when the lens head ring is unscrewed.

7.4 Reflector—The reflector may be of metal or plastic and must have sufficient rigidity so as not to become distorted when the flashlight is completely assembled with cells and lamp. It must have an essentially parabolic reflecting surface, highly polished and resistant to corrosion and discoloration. The reflector shall be 1 ¾ ± ¼ in. (44 ± 6 mm) in diameter.

7.5 Lamps—The lamps shall be appropriate for use with alkaline or carbon-zinc batteries. Each lamp must have a lamp life of at least 15 h at the rated battery voltage.

7.6 Lamp Holder—The lamp shall be firmly positioned in the reflector. It shall be so positioned that the lamp, when assembled in the holder, shall have its filament located at the focus of the reflector, with the accuracy necessary to produce a concentrated beam of light as specified in 9.7. It shall have sufficient rigidity so as not to become distorted when the flashlight is completely assembled with cells and lamp. Means shall be provided to protect the lamp from damage by battery impact and for conveniently removing and replacing the lamp. The mounting adjustment shall have sufficient stability to retain the focal adjustment of the lamp under a condition of vibration, and when the flashlight is tested in accordance with 9.1.2.

7.7 Switch—The switch shall be conveniently located and securely attached to the flashlight. It shall be provided with a permanent “ON” position, a manually operable signaling or “FLASHING” position, and a locked “OFF” position. It shall be provided with means to prevent accidental closing of the lamp circuit. The switch parts and switch contact strip shall be adequately insulated so that it will be impossible for metal-clad cells to close a circuit when the switch is on the “OFF” position. The flashlight shall be designed with a switch guard. Contact springs shall be of phosphor bronze, spring brass, or other corrosion-resistant equivalent material.

7.8 Suspension Member—Each flashlight shall be equipped with a suitable suspension ring or clip. The ring or clip shall be tested as specified in 9.8.

8. Workmanship

8.1 Flashlights shall be of sturdy construction and free of mechanical, electrical, or other imperfections or defects that materially affect appearance or that may affect quality, reliability, or serviceability. The finished flashlight shall not contain rough edges, burrs, blemishes, or other disfigurements and shall be clean, free from rust, toolmarks, pits, and other injurious defects.

8.1.1 Threaded parts shall be smooth and close fitting and shall be capable of being easily moved by hand relative to each other. Threaded parts shall not jump or change adjustment when being put together or when subjected to the tests in Section 9.

9. Test Methods

9.1 Switches:

9.1.1 Switch Leakage—With the lamp and reflector removed, insert fresh batteries into the flashlight. Connect a voltmeter across the switch and battery or the switch and battery contacts, as appropriate, in such a way as to read the battery voltage through the switch. With the switch in the “OFF” position, read the voltage. Any distinguishable deflection of the meter hand when the meter is set in the voltage range, nearest the battery voltage, shall constitute failure of this test.

9.1.2 Operation—Insert batteries into the flashlight and operate the switch five times in each of the three switch positions. Shake the flashlight vigorously in each “ON” and “FLASHING” switch position. The flashlight must not go off when shaken vigorously while the switch is in the “ON” or “FLASHING” position.

9.1.3 Switch Endurance—Test the contact switch mechanism of the flashlight by operating the switch for 25 000 continuous cycles. A cycle shall consist of movements from “OFF” position through the full “ON” and “FLASHING” positions and back to “OFF” position. Operate the switch under normal electrical load conditions, and replace the lamp and batteries as often as required to ensure that the switch mechanism is operating under normal load throughout the 25 000 cycles. Burning out of bulbs and batteries during the test shall not constitute failure of this test. Failure of the switch to complete 25 000 cycles shall constitute failure of this test.

9.2 Watertightness—Test the flashlight as follows:

9.2.1 Submerge the assembled flashlight in a salt water solution (1.04 sp gr) under a head of 1 ft (0.3 m) for a period of 24 h at a water temperature of 65°F (18°C). Remove the flashlight and wipe off the excess water. The total water absorption shall not exceed 5 % weight. The flashlight shall be
capable of being disassembled and reassembled without undue difficulty upon completion of the test and shall be in perfect working order.

9. Impact:

9.3.1 Test Conditions—Place the flashlight, without batteries installed, in a cold chamber at −40 ± 5°F (−40 ± 3°C) for 2 h. With the flashlight stabilized at this temperature, immediately subject it to the low- and high-impact test specified in 9.3.2 and 9.3.3. Apply the point of impact to the following:

9.3.1.1 The outside of the flashlight case at a point midway between the ends of the case on a side 90° from the switch,

9.3.1.2 The switch (in the “ON” position and in the “OFF” position),

9.3.1.3 The lens cap, and

9.3.1.4 The end cap.

9.3.2 Low Impact—Subject the flashlight to a 12-lbf-in. (1.4 N·m) impact using a 1-lb (0.4-kg) steel ball at each of the points of impact specified in 9.3.1. Provided the flashlight remains intact, next subject the flashlight to the watertightness test (see 9.2). There shall be no evidence of breakage from impact or moisture in the case.

9.3.3 High Impact—After the flashlight passes the low-impact test, again place the flashlight in the cold chamber at −40°F ± 5°F (−40 ± 3°C) for 2 h, and then immediately subject it to a 20 lbf-in. (2.3 N·m) impact using a 1-lb (0.4-kg) steel ball at each of the points of impact specified above. There shall be no evidence of damage to the case, the lens, or the end cap.

9.4 Environmental:

9.4.1 Heat and Humidity—Place the flashlight, with dry cells, on a horizontal surface and subject to dry heat at 150 ± 5°F (65.6 ± 3°C) for 16 h, followed by an 85 ± 5 % relative humidity at 100 ± 2°F (38 ± 1°C) for 6 h. The flashlight shall be compared with untested flashlights for dimensional stability, crazing of surface, and then tested to determine that the flashlight operates in accordance with 9.1.2.

9.5 Corrosion—Subject the flashlights, without dry cells, to salt spray for 200 h. Then wash the flashlight with fresh water, dry, and then test to determine that the flashlight operates in accordance with 9.1.2. There shall be no evidence of corrosion.

9.6 Rough Use—Drop the flashlight, complete with dry cells, lamps, and lens, 5 ft (1.5 m) in free fall onto a vinyl-asbestos tiled concrete floor. Drop the flashlight twice in a horizontal position upon the switch, with the switch in the “ON” position, twice in a horizontal position upon the switch, with the switch in the “OFF” position, twice in a vertical position upon the head of the flashlight, and upon the base of the flashlight. Do not tighten parts once the test has begun. There shall be no evidence of damage to any part of the flashlight. Then test the flashlight in accordance with 9.1.3.

9.7 Light Projection—The flashlight must project a concentrated beam of light not less than 5 in. (127 mm) nor more than 11 in. (279 mm) in diameter when located 5 ft (1.524 m) from a screen. The plane of the screen must be perpendicular to the optical axis of the flashlight.

9.8 End Cap Ring—The end cap ring shall support a weight of 25 lb (11.3 kg) for 1 min without evidence of distortion.

10. Marking, Packaging, and Packing

10.1 Product Marking—Each flashlight conforming to all the requirements in this specification shall be marked with the name, brand, or trademark of the manufacturer, this ASTM specification number, the type of flashlight (Type I, Type II, or Type III), and any other information as may be specified in the contract or purchase order.

10.2 Unless otherwise specified by the customer in the contract or purchase order, the flashlight shall be packaged, packed, and marked in accordance with the manufacturer’s commercial practice to ensure acceptance and safe delivery by the carrier for the mode of shipping and handling.


11.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and requirements as specified herein. Except as otherwise specified in the contract or purchase order, the producer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein. The purchaser reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure that the flashlights conform to the prescribed requirements.

11.2 The producer shall perform the necessary inspection and tests to ensure that an S-4 inspection level, in accordance with MIL-STD-105D, is provided. An Acceptable Quality Level (AQL) of 1 % defective for the operational test and the switch leakage test, and an AQL of 4 % for any of the other requirements or tests specified shall be provided. Sample testing shall be in accordance with Table 1.

12. Flashlights for Use in Hazardous Locations on U.S. Flag Merchant Vessels

12.1 Details such as dimensions, construction criteria, battery configuration, and voltage shall be provided by the procuring agency in the contract or purchase order.

12.2 Flashlights that are to be used in hazardous locations shall conform to the requirements of Underwriters Laboratories (UL) Standard No. 783, or equivalent standard, and to the following requirements.

12.3 Flashlights that are to be used in hazardous locations shall be listed by an independent testing laboratory that is concerned with product evaluation, that maintains periodic inspection of production of listed flashlights, and whose listing states that the flashlight has been tested and found suitable for

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**TABLE 1 Sample Testing**

<table>
<thead>
<tr>
<th>Production</th>
<th>Order Batch</th>
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<tbody>
<tr>
<td>1. Switch leakage (9.1.1)</td>
<td>1. Switch leakage (9.1.1)</td>
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<tr>
<td>2. Operation (9.1.2)</td>
<td>2. Operation (9.1.2)</td>
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<tr>
<td>3. Switch endurance (9.1.3)</td>
<td>3. Rough use (9.6)</td>
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<td>4. Watertightness (9.2)</td>
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<td>5. Impact (9.3)</td>
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<td>6. Heat and humidity (9.4.1)</td>
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<td>7. Corrosion (9.5)</td>
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<td>8. Rough use (9.6)</td>
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<td>9. Light projection (9.7)</td>
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<tr>
<td>10. End cap ring (9.8)</td>
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</table>
use in the hazardous location specified (that is, Class and Group designation). The testing laboratory must be acceptable to the appropriate regulatory bodies or the procurement agency.

12.4 Flashlights that have been listed by a testing laboratory meeting the criteria in 12.3 shall affix a label, symbol, or other identifying mark to the flashlight that shall indicate that the flashlight is suitable for use in the hazardous location.
Standard Specification for
Steel Emergency Gear Stowage Locker

This standard is issued under the fixed designation F 1018; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, material, and manufacture of steel emergency gear stowage lockers.

1.2 Emergency gear lockers shall be of four types (see Section 3).

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A36M Specification for Carbon Structural Steel
A 276 Specification for Stainless Steel Bars and Shapes
A 366/A366M Specification for Commercial Steel (CS) Sheet, Carbon (0.15 Maximum Percent) Cold-Rolled
A 513 Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing
A 563 Specification for Carbon and Alloy Steel Nuts
B 36 Specification for Brass Plate, Sheet, Strip, and Rolled Bar
B 124 Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
B 176 Specification for Copper-Alloy Die Castings

2.2 ANSI Standards:
B18.1.1 Small Solid Rivets
B18.6.3 Slotted and Recessed Head Machine Screws and Machine Screw Nuts
B18.21.1 Lock Washers
B27.2 Plain Washers

2.3 Other Documents:
ABS Rules for Building and Classing Steel Vessels
SSPC Specification
AWS D1.1 Welding Code

3. Classification

3.1 Emergency gear lockers shall be classified in four types as follows:

3.1.1 Type I—For stowage of one complete fireman’s outfit, conforming to all requirements of all sections, figures, and details of this specification.

3.1.2 Type 2—For stowage of two complete firemen’s outfits, conforming to all requirements of all sections, figures, and details of this specification.

3.1.3 Type 3—For stowage of one complete fireman’s outfit, with locker dimensions in accordance with Figs. 2, 3, and 4 (dimensions only), and conforming to the requirements of 3.2, 3.3, 4.1, 5.2.4, and Sections 6 and 7 inclusive.

3.1.4 Type 4—For stowage of two complete firemen’s outfits, with locker dimensions in accordance with Figs. 2, 3, and 4 (dimensions only), and conforming to the requirements of 3.2, 3.3, 4.1, 5.2.4, and Sections 6 and 7 inclusive.

3.2 One complete fireman’s outfit shall consist of the following emergency gear (not included in this specification):

3.2.1 Self-contained breathing apparatus (24 by 14 by 11 in. (610 by 355 by 280 mm)).
3.2.2 Recharge air tank (7-in. (180-mm) diameter by 22 in. (560 mm) long).
3.2.3 Set protective clothing, including helmet, gloves, and boots.
3.2.4 Lifeline (150 ft (45 m), 18 by 18 by 10 in. (455 by 455 by 255 mm)).
3.2.5 Three-cell, explosion-proof flashlight with spare cells.
3.2.6 Flame safety lamp.
3.2.7 Fire axe.

3.3 In addition to the equipment listed in 3.2, each locker shall contain space for the following (not part of this specification):

3.3.1 First-aid kit, (1), (10 by 10 by 7 in. (255 by 255 by 180 mm)).

3.3.2 Spare air tanks, as space allows (see Figs. 2, 3, and 4).

4. Ordering Information

4.1 Order using this ASTM designation, year of issue, locker type, and finish.

5. Materials and Manufacture

5.1 Materials—Materials shall be as specified in Table 1.

5.2 Manufacture:

5.2.1 Mandatory dimensions and construction details for Types 1 and 2 are as depicted in Figs. 1-9.

5.2.2 Mandatory dimensions for Types 3 and 4 are as shown in Fig. 2, Fig. 3, and Fig. 5, respectively, and applicable details of Sections “A-A” and “B-B.” Alternative construction details are permissible.

5.2.3 Construction details depicted in Figs. 4-9, while specifically referring to locker Type 2, shall be adapted to suit locker Type 1.
5.2.4 Welded construction, in accordance with ABS Rules for Building and Classing Steel Vessels or AWS D 1.1 Structural Welding Code shall be used throughout, unless otherwise specified.

6. Dimensions and Tolerances

6.1 Dimensions are as indicated.

6.2 Tolerance—±1/16 in. (1.5 mm).
7. Workmanship, Finish, and Appearance

7.1 Entire assembly shall be free of weld spatter, slag, splinters, sharp edges, burrs, projections, and other defects that may be hazardous to personnel.

7.2 The locker shall be cleaned after assembly to a commercial finish in accordance with SSPC-SP6.

7.3 Unless otherwise required by the ordering documents, the unit shall have the manufacturer’s standard baked-on enamel finish.

7.3.1 The color shall be specified in the ordering documents.

8. Keywords

8.1 emergency gear; fireman’s locker; fireman’s outfit; locker; steel locker; stowage locker
NOTE 1—1 in. = 25.4 mm.

FIG. 4 Corner Bracket
FIG. 5 Lock Bolt

Note 1—1 in. = 25.4 mm.

FIG. 5 Lock Bolt
F 1018

FIG. 6 Locking Handle

SECTION "H-H"

Note 1—1 in. = 25.4 mm.

FIG. 6 Locking Handle
FIG. 7 Latch—Miscellaneous Details

NOTE 1—1 in. = 25.4 mm.

FIG. 7 Latch—Miscellaneous Details
Note 1—1 in. = 25.4 mm.

FIG. 8 Leg
NOTE 1—1 in. = 25.4 mm.

FIG. 9 Hinge and Liner
**Table 1: Parts List for Locker Type 2**

<table>
<thead>
<tr>
<th>Description</th>
<th>Item Number</th>
<th>Quantity</th>
<th>ASTM, ANSI Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locker top, sheet, 16 gage</td>
<td>1</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Locker side, right, sheet, 16 gage</td>
<td>2</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Locker side, left, sheet, 16 gage</td>
<td>3</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Locker back, sheet, 16 gage</td>
<td>4</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Locker bottom, sheet, 16 gage</td>
<td>5</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Door, right, sheet, 16 gage</td>
<td>6</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Door, left, sheet, 16 gage</td>
<td>7</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Shelf, full-width, sheet, 16 gage</td>
<td>8</td>
<td>2</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Shelf, half-width, sheet, 16 gage</td>
<td>9</td>
<td>2</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Partition, vertical, sheet, 16 gage</td>
<td>10</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Corner bracket, sheet, 16 gage</td>
<td>11</td>
<td>4</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Door, right, sheet, cast brass</td>
<td>12</td>
<td>1</td>
<td>B176 (UNS C6500)</td>
</tr>
<tr>
<td>Keeper, brass</td>
<td>13</td>
<td>1</td>
<td>B124 (UNS C6700)</td>
</tr>
<tr>
<td>Machine screw, oval-head, #10-24 UNC-2A to length to suit brass</td>
<td>14</td>
<td>14</td>
<td>ANSI B18.6.3, B124 (UNS C6700)</td>
</tr>
<tr>
<td>Nut, hexagon machine, #10-24 UNC-2B, brass</td>
<td>15</td>
<td>14</td>
<td>ANSI B18.6.3, B124 (UNS C6700)</td>
</tr>
<tr>
<td>Escutcheon, sheet, 16 gage × 2 in. long × 1¼ in. wide, brass</td>
<td>16</td>
<td>1</td>
<td>B36</td>
</tr>
<tr>
<td>Locking rod, upper, round bar, ½ in. diameter × 37 in. long, carbon steel</td>
<td>17</td>
<td>1</td>
<td>A36/A36M</td>
</tr>
<tr>
<td>Locking rod, lower, round bar, ½ in. diameter × 37 in. long, carbon steel</td>
<td>18</td>
<td>1</td>
<td>A36/A36M</td>
</tr>
<tr>
<td>Guide, locking rod, tube, ½ in. outside diameter × 0.065 in. wall thickness × 1½ in. long, carbon steel</td>
<td>19</td>
<td>2</td>
<td>A513</td>
</tr>
<tr>
<td>Latch, sheet, 12 gage × 3½ in. long × 2 in. wide, carbon steel</td>
<td>20</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Reinforcing, latch, sheet, 16 gage × 5 in. long × 1½ in. wide, carbon steel</td>
<td>21</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Lock washer, ¾ in. nominal size, carbon steel</td>
<td>22</td>
<td>1</td>
<td>ANSI B18.21.1</td>
</tr>
<tr>
<td>Rivet, brazier head, ½ in. diameter</td>
<td>23</td>
<td>2</td>
<td>ANSI B18.1.1</td>
</tr>
<tr>
<td>Insulation, wool felt, ¾ in. thick × 2 in. long × 1½ in. wide</td>
<td>25</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Reinforcing clip, sheet, 12 gage × 1½ in. square, carbon steel</td>
<td>26</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Reinforcing clip, sheet, 16 gage × 1½ in. square, carbon steel</td>
<td>27</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Cam, sheet, 12 gage × 1½ in. square, carbon steel</td>
<td>28</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Latch filler, sheet, 16 gage × 2½ in. long × 2½ in. wide, carbon steel</td>
<td>29</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Straps, sheet, 16 gage × 2½ in. long × 1 in. wide, carbon steel</td>
<td>30</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Nut, hexagon, ¼ in. UNC-2B, carbon steel</td>
<td>31</td>
<td>1</td>
<td>A563</td>
</tr>
<tr>
<td>Liner, sheet, 16 gage × 1½ in. long × 1½ in. wide, carbon steel</td>
<td>32</td>
<td>1</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Hinge, sheet, 16 gage × 3 in. long × 1½ in. wide, carbon steel included: ½ in. diameter × 1½ in. long Stainless steel pin</td>
<td>33</td>
<td>6</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Lock washer, ½ in. nominal size, ½ in. inside diameter, carbon steel</td>
<td>34</td>
<td>12</td>
<td>ANSI B18.21.1</td>
</tr>
<tr>
<td>Liner, hinge, sheet, 16 gage × 2 in. long × ¾ in. wide, carbon steel</td>
<td>35</td>
<td>6</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Leg, angle, 1×1×6 in. long, carbon steel</td>
<td>36</td>
<td>4</td>
<td>A36/A36M</td>
</tr>
<tr>
<td>Foot pad, sheet, 10 gage × 1½ in. square, carbon steel</td>
<td>37</td>
<td>4</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Leg bracket, sheet, 10 gage × 8 in. long × 3 in. wide, carbon steel</td>
<td>38</td>
<td>4</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Leg reinforcement, sheet, 10 gage × 8 in. long × 1½ in. wide—bend to form ¾ in. × ¾ in. angle, carbon steel</td>
<td>39</td>
<td>4</td>
<td>A36/SA36M</td>
</tr>
<tr>
<td>Machine screw, ¼ in. UNC-2A, carbon steel</td>
<td>40</td>
<td>16</td>
<td>ANSI B18.6.3</td>
</tr>
<tr>
<td>Nut, hexagon machine, ¼ in. UNC-2B, carbon steel</td>
<td>41</td>
<td>16</td>
<td>ANSI B18.6.3</td>
</tr>
<tr>
<td>Lock washer, ½ in. nominal size, carbon steel</td>
<td>42</td>
<td>16</td>
<td>ANSI B18.21.1</td>
</tr>
</tbody>
</table>
Standard Specification for Steel Deck Gear Stowage Box [Metric]

This standard is issued under the fixed designation F 1019M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, material, and manufacture of steel deck gear stowage boxes.

1.2 This specification shall not be used for life preserver or pyrotechnic stowage.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A36M Specification for Carbon Structural Steel
A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

2.2 Other Documents:
ABS Rules for Building and Classing Steel Vessels
SSPC Specification
AWS D1.1 Structural Welding Code

3. Classification

3.1 Deck Gear Stowage Boxes, shall be the following types:
3.1.1 Type I—Conforming to all dimensions in Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8, and Fig. 9.
3.1.2 Type II—Conforming only to Fig. 1 configuration and meeting the requirements of Sections 4-7, dimensions and material specification made to fit unique requirements of customer.

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1 This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.
3 Annual Book of ASTM Standards, Vol 01.06.
4 Available from American Bureau of Shipping, ABS Plaza, 16855 Northchase Dr., Houston, TX 77060.
5 Available from Steel Structures Painting Council, 4400 5th Ave., Pittsburgh, PA 15213.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.
4. Ordering Information

4.1 Order using this ASTM designation, year of issue, and type.

5. Materials and Manufacture

5.1 Materials:

5.1.1 The steel for the deck box shall be in accordance with Specification A 36/A 36M.

5.1.2 Nuts, bolts, and washers shall be corrosion-resistant materials.

5.1.3 Materials used in construction of this box and its packaging shall be free of asbestos and cadmium.

5.2 Manufacture:

5.2.1 Stowage boxes shall be constructed in accordance with figures appearing in this standard.

5.2.2 Welding shall be in accordance with ABS Rules for Building and Classing Steel Vessels or AWS D1.1 Structural Welding Code unless otherwise specified.

6. Dimensions and Tolerances

6.1 Dimensions are as indicated.

6.2 Tolerance—1.5 mm (±1/16 in.).

7. Workmanship, Finish, and Appearance

7.1 The entire assembly shall be free of weld spatter, slag, splinters, sharp edges, projections, and other defects that may be hazardous to personnel.

7.2 The box shall be cleaned after assembly to a commercial finish in accordance with SSPC-SP6.

7.3 All surfaces except gratings and covers shall be coated with one coat of commercial quality anticorrosive, lead-free, chromate-free primer to a minimum dry film thickness of 50 µm.

7.4 Gratings and covers shall be galvanized in accordance with Specification A 123/A 123M.

8. Keywords

8.1 box; deck gear stowage boxes; locker; marine; marine stowage boxes; ship; stowage boxes
FIG. 5 Rod

10 DIAMETER ROC, STEEL, GALVANIZED
25 (TYPICAL)

10 WIDE WASHER
8 (TYPICAL)

4 X 45° CHAMFER (TYPICAL)

CLIP DETAIL "B"

TACK

4

COVER

FIG. 6 Handle

10 DIAMETER BAR

COVER

100

200

(2) – 10 WIDE WASHER, STEEL, GALVANIZED
(1) – 2 COTTER PIN, STEEL, GALVANIZED

CLIP

4 PLATE OR 40 X 40 ANGLE

12 DIAMETER DRILL HOLE

DETAIL "B" CLIP

DETAL "C"

FIG. 5 Rod

FIG. 6 Handle
FIG. 7 Flange

SECTION "B – B"

NOTE: RIGHT COVER NOT SHOWN

FIG. 8 Flange

SECTION "D – D"

SECTION "C – C"

FIG. 8 Flange

SECTION "D – D"
FIG. 9 Box Mounting

GRIND CORNER TO SUIT LEG INSTALLATION

75 x 75 x 10 ANGLE

DRILL (4) 10 HOLES PER SUPPORT LEG FOR BOLT, WASHER, & NUT FASTENING (TYPICAL)

DECK

REMOVABLE

GRIND CORNER TO SUIT LEG INSTALLATION

75 x 75 x 10 ANGLE

DECK

PERMANENT

Fig. 9 Box Mounting
Standard Specification for
Line-Blind Valves for Marine Applications

1. Scope

1.1 This specification provides the minimum requirements for design fabrication, pressure rating, and testing for line-blind valves.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 5, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
   A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless  
2.2 ANSI Standards:
   B16.5 Pipe Flanges and Flanged Fittings, Steel-Nickel Alloy and Other Special Alloys  
B31.1 Power Piping

2.3 MSS Standards:
   SP-6 Finish for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings  
SP-25 Marking System for Valves, Fittings, Flanges, and Unions  
SP-55 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Visual Method)  

2.4 ASME Standard:
   ASME Boiler and Pressure Vessel Code, Sections II, VIII, IX

3. Descriptions of Terms Specific to This Standard

3.1 blank—a solid one-piece circular unit inserted into a pipeline to prevent flow.

3.2 line-blind valve—an assembly consisting of a spectacle plate, bolting, and body, the purpose of which is to provide a convenient means to align a piping system to an open or positively closed configuration. The assembly is designed to provide a simplified method of changing over the flow control spectacle plate without the necessity of plate removal from the valve body.

3.3 spectacle plate, (also spectacle blind)—a figure-eight-shaped unit with one end open for flow and the other solid to prevent flow.

4. Materials and Manufacture

4.1 Materials:
   4.1.1 Materials for spectacle plates, bolting, and body shall be those contained in ASME Section II. For the purpose of stress calculations, ASME Section VIII values shall be used.
   4.1.2 All welding shall be done with procedures and welders qualified in accordance with ASME Section IX and 80% weld efficiency factor shall be used.
   4.1.3 All castings shall be visually inspected and acceptable in accordance with MSS-SP-55.

4.2 Manufacture:
   4.2.1 The spectacle plate shall be designed in accordance with ANSI B31.1, Paragraph 104.5.3.
   4.2.2 The calculations of 4.2.3 and 4.2.4 shall ensure that a line blind is designed for the gasket material, of all that can be used with the line blind being designed, that imposes the most critical bolt-load conditions as a result of its gasket factor, \( m \), and gasket or joint-contact-surface unit seating load, \( y \).
   4.2.3 The bolting shall be either of the following:
   4.2.3.1 Modify the external loads in accordance with ASME B31.1, Paragraph 104.5.3.
   4.2.3.2 The equivalent in cross section to that of ANSI B16.5 flange bolting of equivalent nominal size and pressure.
   4.2.3.3 In no case shall bolts have a nominal diameter less than \( \frac{1}{2} \) in. (12.7 mm).
   4.2.3.4 The material class shall be an approved ANSI B16.5 material or equal in tensile strength.
   4.2.3.5 Cast bolting shall be X-rayed or have an 80% efficiency factor applied.

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.
2 Annual Book of ASTM Standards, Vol 01.01.
3 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.
4 Available from Manufacturer’s Standardization Society of the Valve and Fittings Industry, Inc., 1815 N. Fort Myer Dr., Arlington, VA 22209.
4.2.4 The body shall be calculated using ASME Section VIII, Division 1, Appendix 2 with consideration for the size and material of bolting in the appendix, the bolt load satisfying Note 2 of Paragraph 2-5 of Appendix 2.

4.2.5 The spectacle plate and mating body facings shall be in accordance with MSS-SP-6.

5. Testing

5.1 Each valve body shall be hydrostatically tested to the shell test pressure in accordance with ANSI B16.5, Table 3. A valve supplied to the WOG standard shall be tested up to the nearest ANSI Class.

5.2 Each valve shall be tested for leakage at pressure 1.5 times the cold water rating of the valve rounded upward to the next higher 25-psi (170-kPa) increment. Acceptance criteria shall be that no leakage occurs during a 10-min “hold time” at pressure.

6. Calculations

6.1 Bolting calculations from ASME Section VIII, Division 1, Appendix 2 shall be modified to account for an externally applied load as a result of piping. Add to the minimum required bolt load for the operating conditions, \( W_{m1} \), an external moment bolt load, \( H_x \), such that the modified total cross-sectional area of the bolts shall be as follows:

\[
A'_{m1} = (W_{m1} + H_x)/S_b
\]

where:

- \( H_x = SZ/d_b \)
- \( Z = \Pi((D^4_o - D^4_{i})/D_o)/32, \)
- \( D_i = D_o - 2t_p, \)
- \( t_p = PD_l/(2(0.875)(S)), \) but not less than 0.25 in. (6.4 mm), and
- \( d_b = C\Pi + 2((G_o^3 - G_i^3)/(G_o^2 - G_i^2))3\Pi. \)

6.1.1 All terms are identical to those defined in ASME Section VIII, Appendix 2 with the addition of the following:

6.1.1.1 \( A'_{m1} \) = modified total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for the operating conditions, square inch (square millimetre).

6.1.1.2 \( H_x = \) external moment of bolt load, lbf (N).

6.1.1.3 0.875 = assumed pipe wall tolerance factor.

6.1.1.4 \( S = \) ASME allowable stress of the pipe material at design temperature, psi (kPa) (for purposes of meeting this specification, 15 000 psi (103.4 MPa) from Specification A 53/A53M, Grade B, Type S shall be acceptable).

6.1.1.5 \( Z = \) section bolt load, square inch (square millimetre).

6.1.1.6 \( D_o = \) nominal outside diameter of pipe, inches (millimetres).

6.1.1.7 \( D_i = \) calculated inside diameter of pipe, inches (millimetres).

6.1.1.8 \( t_p = \) calculated pipe wall thickness, inches (millimetres).

6.1.1.9 \( d_b = \) moment arm of external moment on bolts and gasket, inches (millimetres).

6.1.1.10 \( G_o = \) outside diameter of contact surface of gasket, inches (millimetres).

6.1.1.11 \( G_i = \) inside diameter of contact surface of gasket, inches (millimetres).

6.2 The selection of bolts to be used shall be made such that the actual total cross-sectional area of bolts, \( A_m \), will not be less than \( A_{m1} \), where \( A_m \) is taken as the greater of \( A'_{m1} \) and \( A_{m2} \).

7. Product Marking

7.1 Each valve must have the following markings in accordance with MSS-SP-25:

7.1.1 Manufacturer’s name and trademark.

7.1.2 Appropriate pressure class.

7.1.3 Size of end connection.

7.1.4 ASTM designation of materials.

7.1.5 ASTM designation and year of issue of this specification.

8. Keywords

8.1 blind valve; line-blind valve; marine technology; piping system; ship; valve
1. **Scope**

   1.1 This practice provides guidance in the selection of manual and power-actuated valve operators.

   1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

   1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. **Referenced Documents**

   2.1 ANSI Standard:
   
   B16.5 Pipe Flanges and Flanged Fittings

3. **List of Valve Operator Types**

   3.1 **Manual Operators:**
   
   3.1.1 Handwheels.
   
   3.1.2 Tee-wrenches.

   3.2 **Electric Operators:**
   
   3.2.1 Stem Nut Driven.
   
   3.2.2 Handwheel Driven.

   3.3 **Pneumatic Operators:**
   
   3.3.1 Stem Nut Driven.
   
   3.3.2 Handwheel Driven.

   3.4 **Hydraulic Operators:**
   
   3.4.1 Stem Nut Driven.
   
   3.4.2 Handwheel Driven.

4. **General Requirements**

   4.1 General requirements apply to all types of valve operators.

   4.2 Operating terminals shall be accessible during all service conditions but shall not constitute an obstruction in working spaces.

   4.3 Valve controls that are not immediately identifiable as to service shall be fitted with name plates.

   4.4 Valve operating stations shall be fitted with a valve position indicator unless valve position is obvious for the service intended (full open or full closed), or valve is classified damage control smaller than 1½ in. (38.1 mm).

   4.5 Positioning of the valve by either the local or remote actuators shall not void the ability of any other actuator to position the valve.

   4.6 All valves, regardless of size, shall be readily operable by one man in a reasonable and limited time period, either through a manual or power-actuated valve operator.

5. **Manual Valve Operators**

   5.1 Material for handwheels and tee-wrenches for casualty or damage control shall be either malleable iron, ductile iron, or steel.

   5.2 Portable valve wrenches shall be labeled and stored near the valve operating station. Valve operating wrenches shall fit and turn (to open and close) deckbox operator covers.

   5.3 Valves shall be located to prevent the necessity for ratchet wrenches wherever possible. Ratchet wrenches are, however, permitted where valve location prevents complete wrench rotation.

   5.4 Handwheel diameter and tee-wrench handle length, based on the system torque at the operating station, is presented in Table 1.

6. **Requirements for Power-Actuated Valve Operators**

   6.1 Requirements for power-actuated operators apply to electric, pneumatic, and hydraulic valve operators.

   6.2 All power-actuated valves, except for valves within tanks, shall have a means for local, manual operation. Manual operation shall override power operation of the valve. Stem nut driven electric, pneumatic, and hydraulic operators shall return to the power mode after manual reset.

   6.3 To prevent personnel injury during remote actuation of the valve, the manual handwheel shall be either the solid disk type, or it shall have a spoke cover plate or handwheel enclosure, or it shall disengage so that it does not rotate.

   6.4 Valve actuators in critical systems may be provided with an energy storage system with sufficient capacity to cycle the valve once (from the initial position to the opposite and return).
7. Electric Valve Operators

7.1 The valve operator shall be powered by the ship’s service power system. Critical valve operators may be additionally powered by an emergency power system.

7.2 Handwheel acting operators shall consist of the electric motor, gearing, limit and torque switches, reversing starter and pilot lights, and permanently mounted handwheel to form a complete self-contained unit to be mounted directly on the valve or through a reach rod transmission with flanges in accordance with ANSI B16.5.

7.2.1 Renewable stem nuts shall be provided for stem acting operators instead of the permanently mounted handwheels.

7.3 The operator shall be suitable for marine service rated for the ambient temperature in which it will operate. For weather deck applications 104°F (40°C) is considered standard. For machinery spaces 122°F (50°C) is standard.

7.4 The motor shall be one of the following:

7.4.1 Single Phase, 115 Vac, capacitor start, capacitor run.

7.4.2 Three Phase, 460 Vac.

7.4.3 Both types shall have insulation of Class B or Class F with Class B temperature rise. The motor shall have built-in thermal and overload protection.

7.5 The operator shall transmit power from the motor to the valve stem, valve handwheel, or reach rod transmission system through a bevel gear, worm gear, or planetary gear system. Ball or roller bearings shall be used throughout.

7.6 The gear system shall not permit backdrive through the operator upon interruption of electric power.

7.7 The closing and opening operation shall be regulated by means of a travel-activated device and a torque-activated device as a backup.

7.8 The operator enclosure shall be explosion proof and submersible, with submersible electric connections where service conditions dictate.

8. Pneumatic Valve Operators

8.1 Position indication of pneumatic-actuated valves shall be accomplished by a self-indicating air cock and a pressure gage or other acceptable means installed in the actuating line as close to the control board as possible.

8.2 Systems with a maximum allowable working pressure in excess of 150 lb/in.² (10.3 bar) shall be designed with a surge tank or other acceptable means of pulsation dampening.

8.3 The system shall be designed so that proper functioning of any unit shall not be affected by back pressure in the system.

8.4 Suitable drains shall be provided at low points of piping systems.

9. Hydraulic Valve Operators

9.1 Each hydraulic operating system shall be self-contained including the necessary piping and a reservoir tank for the operating fluid. Back pressure in the system shall not effect the proper functioning of any system component.

9.2 Systems using hydraulic motors shall have a design pressure of sufficient magnitude for the intended use.

9.3 Systems with piston- or diaphragm-type hydraulic operators shall have a design pressure equal to the design pressure of the piston or diaphragm and shall have relief valve protection.

9.4 The hydraulic fluid used shall have a flashpoint of not less than 199.4°F (93°C) for pressures below 150 lb/in.² (10.3 bar) and 316.4°F (158°C) for pressures of 150 lb/in.² and above.

9.5 The hydraulic fluid shall be suitable for operation of the system through the entire temperature range to which it may be subjected in service.

9.6 Motors shall be installed directly on valves or through a gear system to produce the necessary valve speed or torque.

9.7 Pumps and control cocks at remote operating stations shall be mounted on panels with the reservoir tank located above the suction of the pumps. Four-way plug cocks shall be arranged to transit pressure for opening and closing the valves. Cocks shall have a neutral position to allow for expansion of operating oil that may be trapped in the system and to prevent inadvertent operation.

9.8 The minimum number of pumps at a remote operating station for a system shall be in accordance with Table 2.

9.9 Multiple pumps shall be connected in parallel.

---

TABLE 1 Handwheel Diameters and Tee-Wrench Handle Lengths

<table>
<thead>
<tr>
<th>Torque, lbf·ft</th>
<th>Tee-Wrench Handle Length, in. (mm)</th>
<th>Handwheel Diameter, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>10 (254)</td>
<td>2 (50.8)</td>
</tr>
<tr>
<td>12.3</td>
<td>10 (254)</td>
<td>3 (76.2)</td>
</tr>
<tr>
<td>17.7</td>
<td>10 (254)</td>
<td>4 (101.6)</td>
</tr>
<tr>
<td>23.3</td>
<td>10 (254)</td>
<td>5 (127.0)</td>
</tr>
<tr>
<td>29.5</td>
<td>10 (254)</td>
<td>6 (152.4)</td>
</tr>
<tr>
<td>35.3</td>
<td>12 (304.8)</td>
<td>7 (177.8)</td>
</tr>
<tr>
<td>41.3</td>
<td>12 (304.8)</td>
<td>8 (203.0)</td>
</tr>
<tr>
<td>47.6</td>
<td>20 (508)</td>
<td>9 (229.6)</td>
</tr>
<tr>
<td>54.2</td>
<td>20 (508)</td>
<td>10 (254.0)</td>
</tr>
<tr>
<td>61.0</td>
<td>20 (508)</td>
<td>11 (279.4)</td>
</tr>
<tr>
<td>67.5</td>
<td>20 (508)</td>
<td>12 (304.8)</td>
</tr>
<tr>
<td>80.5</td>
<td>20 (508)</td>
<td>14 (355.6)</td>
</tr>
<tr>
<td>94.0</td>
<td>20 (508)</td>
<td>16 (406.4)</td>
</tr>
<tr>
<td>108.0</td>
<td>...</td>
<td>18 (457.2)</td>
</tr>
<tr>
<td>128.6</td>
<td>...</td>
<td>21 (533.4)</td>
</tr>
<tr>
<td>150.0</td>
<td>...</td>
<td>24 (609.6)</td>
</tr>
<tr>
<td>168.8</td>
<td>...</td>
<td>27 (685.8)</td>
</tr>
<tr>
<td>187.5</td>
<td>...</td>
<td>30 (762.0)</td>
</tr>
<tr>
<td>225.0</td>
<td>...</td>
<td>36 (914.4)</td>
</tr>
</tbody>
</table>

---

TABLE 2 Hydraulic Pump Schedule

<table>
<thead>
<tr>
<th>Number of Pumps, min</th>
<th>Number of Valves Operated, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>
Standard Specification for Doors, Double, Gastight/Airtight, Individually Dogged, for Marine Use

This standard is issued under the fixed designation F 1068; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification, to be used in conjunction with Specification F 1073, covers the principal dimensions and the mechanical requirements for manufacturing steel and aluminum individually dogged, airtight/gastight double doors for personnel access through bulkheads, complete with frames, intended to maintain the structural and the air and gas tightness integrity of the bulkheads.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the Test Methods portion, Section 6, of this specification: This standard does not purport to address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
   A 36/A 36M Specification for Carbon Structural Steel
   A 131/A 131M Specification for Structural Steel for Ships
   B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
   F 1073 Specification for Door Fittings, for Watertight/Gastight/Airtight, Weathertight, and Non-Tight Doors, for Marine Use

2.2 ABS Standard:
   Rules for Building and Classing Steel Vessels

2.3 Military Standards:
   MIL-R-900 Rubber Gasket Material, 45 Durometer Hardness
   MIL-C-81706 Coating, Aluminum and Aluminum Alloys
   MIL-P-24441 Epoxy-Polyamide Paint
   DoD-STD-2138 Metal Sprayed Coating System for Corrosion Protection
   TT-E-490 Enamel, Silicone Alkyd Copolymer, Semi-Gloss, Exterior
   ZZ-R-765 Rubber, Silicone

3. Ordering Information

3.1 Ordering for doors under this specification shall include the following:
   3.1.1 Material of doors,
   3.1.2 Nominal and ASTM designations, fixed lights or no lights,
   3.1.3 Quantity, and
   3.1.4 Location of active and inactive panels.

3.2 Inspection and acceptance of doors shall be agreed upon between the purchaser and the supplier.

4. Construction, Shape, and Dimensions

4.1 The construction, shape, and clear opening dimensions shall be as shown in Fig. 1 and Table 1; in addition, they shall conform to the following requirements:
   4.1.1 Door frames shall be supplied as indicated in Fig. 1. The corner radius inside of door frame shall be 8 in. (203 mm).
   4.1.2 Dogs shall be located on the door panels unless otherwise specified.
   4.1.3 The doors shall be fitted with dogs, hinges, hasp and staple assemblies, grab handles, label plates, and hook assemblies.
   4.1.4 The position of the grab handles shall be located at the center of the height of each door panel.
   4.1.5 The components shall be attached to the steel doors. Components shall be attached to aluminum doors by either welding or bolting.
   4.1.6 The material of standard door components shall be as given in Table 2.
4.1.7 Welding shall be done in accordance with ABS Rules for Building and Classing Steel Vessels.

5. Workmanship, Finish, and Appearance

5.1 All sharp and ragged edges shall be ground flush and removed for personnel protection.

5.1.1 The door panels, upon completion, shall be straight with a tolerance of $\pm \frac{1}{16}$ in. (1.6 mm).

5.2 Pretreatment and priming of door components shall be as follows:

5.2.1 Steel door and components, except component No. 3, are to be coated with inorganic zinc rich primer, SSPC Paint 20 Type I-C, at 1.5 to 3.0 mils (MDFT), both sides, before assembly, following surface preparation in accordance with the manufacturer’s instructions.

5.2.2 Aluminum door and components, except component No. 3, are to be pretreated with vinyl wash primer coating, followed with lead free, chromate free, anti-corrosion prime coating. Pretreatment and primer are to be applied before
assembly, following surface preparation in accordance with the manufacturer’s instructions.

6. Test Methods

6.1 Design all doors with their respective fittings from the inside (stiffener side) to a test head of 5 psi (34 kPa) and a proof test of 7.5 psi (50 kPa) to ensure no deformation of the panel.

6.2 Before delivery certify the doors for gastight/airtight integrity.

7. Product Marking

7.1 Each door shall be marked with the purchase order number by attaching a CRES label plate to the door panel using letters at least 1⁄2 in. (13 mm) high, designating the ASTM designation number, nominal number, thickness of the door plate, and direction of opening. Other markings may be in paint.

7.2 Label plates shall be screwed or bolted to the door panel on steel and aluminum doors, but in no way adversely affect the airtightness or gas tightness.

8. Packaging and Package Marking

8.1 Doors shall be crated or attached to a pallet in a manner acceptable for shipment by a common carrier. The door and door frame assembly shall be shipped as one unit with the gasket protected from knife edges by an inserted partition.

9. Keywords

9.1 airtight; dogged; doors; double doors; gastight; marine; ship

**SUPPLEMENTARY REQUIREMENTS**

The following supplementary requirements shall apply only when specified by the contract or order.

**S1. Painting**

S1.1 Pretreatment and priming of door components shall be metal spray coating in accordance with DoD-STD-2138, Type II on both sides prior to assembly.

S1.2 Aluminum door and components shall be treated with a chemical conversion coating MIL-C-81706, second primed with one coat epoxy polyamide primer (Formula 150 of MIL-P-24441) alkyd haze-gray (TT-E-490 or equal). Apply coating before assembly, following surface preparation in accordance with the manufacturer’s instruction.

**S2. Internal Pressure**

S2.1 Design and proof test pressures other than 5 and 7.5 psi (34 and 52 kPa), respectively, if required, shall be indicated.

S2.2 Clear openings other than those specified in Table 1, if required, shall be indicated.
S3. Special Heat Resisting Gaskets
   S3.1 Special heat resisting gaskets in accordance with ZZ-R-765, Class 3B, Grade 30 are to be installed.

S4. Aluminum Doors
   S4.1 Aluminum doors for 5 psi (34 kPa) internal and external pressures are to be indicated.

S5. Additional Test Requirements
   S5.1 Test requirements, when indicated, shall allow 1 out of 50 doors to be tested for 1.5 times the test requirements performed by the manufacturer.
Standard Specification for Doors, Watertight, Gastight/Airtight and Weathertight, Individually Dogged, for Marine Use

This standard is issued under the fixed designation F 1069; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification, to be used in conjunction with Specification F 1073, covers the principal dimensions and the mechanical requirements for manufacturing steel, aluminum, and glass-reinforced plastic, individually dogged, watertight, gastight/airtight, and weathertight doors, for personnel access through bulkheads, complete with frames, for marine use intended to maintain the structural and tightness integrity of bulkheads.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains to the test method portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A36M Specification for Carbon Structural Steel²
A 131/A131M Specification for Structural Steel for Ships²
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate³
F 1073 Specification for Door Fittings, for Watertight/Gastight/Airtight, Weathertight, and Non-Tight Doors, for Marine Use⁴
2.2 ABS Standard:
Rules for Building and Classing Steel Vessels⁵
2.3 Military Standards:
MIL-R-900 Rubber Gasket Material (45 Durometer Hardness)⁶
MIL-R-21607 Resins, Polyester Low-Pressure Laminating Fire Retardant⁶
MIL-P-17549 Plastic Laminates, Fibrous Glass Reinforced⁶
MIL-G-17927 Gaskets, Glass-Metallic Cover, Silicone Core⁶
MIL-C-81706 Coating, Aluminum and Aluminum Alloys⁶
MIL-P-24441 Epoxy-Polyamide Paint⁶
DoD-STD-2138 Metal Sprayed Coating Systems for Corrosion Protection⁶
TT-E-490 Enamel Silicone Alkyd Copolymer, Semi-gloss Exterior⁶

3. Classification

3.1 The doors shall be classified into groups as given in Table 1, according to their application; in addition, the length “L” shall be in accordance with the ABS Rules for Building and Classing Steel Vessels.

3.2 The doors shall be of two types. Type I doors shall conform to all dimensions, scantlings, and details of this specification. Type II doors shall be to special openings conforming to the test methods of this specification and scantlings indicated in Figs. 1-4. Special built doors with more than 9 psi (62 kPa) shall be indicated in the ordering information (see Supplementary Requirements).

3.2.1 Tolerances of all doors shall be ±1/8 in. (3 mm).

3.3 Where structural fire protection requirements are applicable, the doors shall meet the same requirements as required for the bulkheads in which fitted.

4. Ordering Information

4.1 Orders for doors, under this specification, shall include the following:
4.1.1 Group (see Table 1), type of material and dimensions (see Tables 2-5 inclusive) of doors,
4.1.2 Nominal and ASTM designations indicating fixed lights or no lights,
4.1.3 Quantity of each hand of door (right hand/left hand),
4.1.4 Test head to be indicated when Type II door is
required, and
4.1.5 Hasp and staple assemblies.

4.2 Inspection and acceptance of doors shall be agreed upon
between the purchaser and the supplier.

5. Materials and Manufacture

5.1 The materials and specifications shall be as shown in
Table 5.

5.2 Glass-reinforced plastic (GRP) material of doors and
frames shall meet the requirements of MIL-P-17549, Grade 1.
In addition, laminate must have the flammability limits equal to
the requirements for Grade 2, Class A, of MIL-R-21607.

5.2.1 All GRP material that is drilled, cut, and sanded,
leaving the surface exposed, shall be sealed with the same resin
as the exposed material.

6. Construction, Shape, and Dimensions

6.1 The construction, shape, and clear opening dimensions
shall be as shown in Table 2, Table 3, Table 4, and Fig. 1, Fig.
2, and shall also conform to the following:

6.1.1 A right-hand opening door shall be construed as one
that opens toward you with hinges located on right side of door.
A left-hand opening is similar but with hinges on the left.

6.1.2 Door frames shall be supplied as indicated in Fig. 4.
The corner radius, inside of door frame, shall be 8 in. (203
mm).
6.1.3 Dogs shall be located on the door panels unless otherwise specified. To hold dogs in open position, steel wedges or equivalent shall be welded to the panels.

6.1.4 Doors shall be fitted with dogs, hinges, grab handles, label plates, and hook assemblies; for details, see Specification F 1073.

6.1.5 Doors shall be fitted with hasp and staple assemblies if so specified by the purchaser in the ordering information.

6.1.6 The material for the standard door components shall be as shown in Table 5.

6.1.7 Welding shall be done in accordance with the Rules of the American Bureau of Shipping (indicated in Section 30).

7. Workmanship, Finish, and Appearance

7.1 All sharp and ragged edges shall be ground flush and removed for personnel protection.

7.2 Pretreatment and priming of door components shall be as follows:

7.2.1 Steel door and components shall be coated with inorganic zinc-rich primer SSPC Paint 20 Type I-C at 1.5 to 3.0 mil (MDFT) both sides, before assembly, following surface preparation in accordance with the manufacturer’s instructions.

7.2.2 Aluminum door and components are to be pretreated with wash primer coating followed with lead-free, chromate-free, anticorrosion prime coating. Pretreatment and primer are to be applied before assembly, following surface preparation, in accordance with the manufacturer’s instructions.

7.2.3 GRP door and components are to have color tint “haze gray” painted upon completion of the molding process.

8. Test Methods

8.1 Design all steel watertight doors with their respective fittings to an internal pressure of 9 psi (62 kPa). Watertight aluminum and GRP doors shall be 5 psi (34 kPa). Design gastight/airtight doors to an internal pressure of 2 psi (14 kPa).

8.2 Before delivery, certify the doors applicable to watertight, airtight, or weathertight integrity.

9. Product Marking

9.1 Each door shall be marked with the purchase order number by attaching a CRES label plate to the door panel using letters at least ½ in. (12.7 mm) high, indicating the ASTM designation number, class, nominal number, thickness of door plate, and direction of opening. Other markings may be in paint.

9.2 Label plates shall be screwed or bolted to the door panel on steel and aluminum doors, but in no way adversely affect the watertightness.

9.3 GRP door label plates shall be affixed to the door, with epoxy.

10. Packaging and Package Marking

10.1 Doors shall be crated or attached to a pallet in a manner acceptable for shipment by a common carrier. The door and door frame assembly shall be shipped as one unit with gasket protected from knife edge by an inserted partition.

11. Keywords

11.1 airtight; bulkheads; doors; gastight; marine; ship; tightness integrity; watertight; weathertight
TYPICAL EDGE SECTION

FIG. 4 In Way of Steel Door Frame

TABLE 2 Doors—Watertight, Gastight/Airtight

<table>
<thead>
<tr>
<th>NOMINAL NO.</th>
<th>CLEAR OPENING</th>
<th>SIZE OF DOOR</th>
<th>THICKNESS DOOR PLATE</th>
<th>SIZE OF STIFFENER</th>
<th>THICKNESS OF DOOR</th>
<th>SIZE OF STIFFENER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 1/4 in.</td>
<td>5/16 in.</td>
<td>3 1/2 in.</td>
<td>3 1/8 in.</td>
</tr>
<tr>
<td>2045</td>
<td>20 X 45</td>
<td>28 X 47</td>
<td>3/8 in.</td>
<td>5/16 in.</td>
<td>3 1/2 in.</td>
<td>3 1/8 in.</td>
</tr>
<tr>
<td>2054</td>
<td>20 X 54</td>
<td>28 X 56</td>
<td>3/8 in.</td>
<td>5/16 in.</td>
<td>3 1/2 in.</td>
<td>3 1/8 in.</td>
</tr>
<tr>
<td>2057</td>
<td>20 X 57</td>
<td>28 X 59</td>
<td>3/8 in.</td>
<td>5/16 in.</td>
<td>3 1/2 in.</td>
<td>3 1/8 in.</td>
</tr>
<tr>
<td>2065</td>
<td>20 X 65</td>
<td>28 X 68</td>
<td>3/8 in.</td>
<td>5/16 in.</td>
<td>3 1/2 in.</td>
<td>3 1/8 in.</td>
</tr>
<tr>
<td>2062</td>
<td>20 X 60</td>
<td>28 X 68</td>
<td>3/8 in.</td>
<td>5/16 in.</td>
<td>3 1/2 in.</td>
<td>3 1/8 in.</td>
</tr>
</tbody>
</table>

Note 1—1 in. = 25.4 mm.
Note 2—2.2 lb = 1 kg.
Note 3—The length "L" shall be in accordance with the Rules for Building and Classing Steel Vessels by ABS. Weight does not include fittings.
### TABLE 3 GRP Doors

<table>
<thead>
<tr>
<th>NOMINAL NO.</th>
<th>CLEAR OPENING</th>
<th>SIZE OF DOOR</th>
<th>C &amp; D</th>
<th>CALCULATED WEIGHT (LBS)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2651</td>
<td>26 x 45</td>
<td>28 x 47</td>
<td>1&quot; POLYURETHANE CORE WITH 3/16&quot; FACE SHEETS</td>
<td>36</td>
<td>SEE DMG. NO. 604-66009S, 900, 901, B 827</td>
</tr>
<tr>
<td>2654</td>
<td>26 x 54</td>
<td>28 x 50</td>
<td>INCLUDING MILD STEEL 5' APART</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>2657</td>
<td>26 x 57</td>
<td>20 x 50</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2660</td>
<td>26 x 60</td>
<td>28 x 60</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3063</td>
<td>30 x 63</td>
<td>32 x 65</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3064</td>
<td>30 x 64</td>
<td>32 x 66</td>
<td>61</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE 1**—1 in. = 25.4 mm.
**NOTE 2**—2.2 lb = 1 kg.
**NOTE 3**—For steel doors, see Table 2.
**NOTE 4**—For aluminum doors, see Table 4.
**NOTE 5**—Weight does not include fittings.

### TABLE 4 Aluminum Doors

<table>
<thead>
<tr>
<th>NOMINAL NO.</th>
<th>CLEAR OPENING</th>
<th>SIZE OF DOOR</th>
<th>THICKNESS</th>
<th>SIZE OF STIFFENER</th>
<th>WEIGHT</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2651</td>
<td>26 x 45</td>
<td>28 x 47</td>
<td>1/4&quot;</td>
<td>2 x 2 x 1/4&quot; &quot;T&quot; BAR</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>2654</td>
<td>26 x 54</td>
<td>28 x 50</td>
<td>1/4&quot;</td>
<td>2 x 2 x 1/4&quot; &quot;T&quot; BAR</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>2657</td>
<td>26 x 57</td>
<td>20 x 50</td>
<td>1/4&quot;</td>
<td>2 x 2 x 1/4&quot; &quot;T&quot; BAR</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>3063</td>
<td>30 x 63</td>
<td>32 x 65</td>
<td>1/4&quot;</td>
<td>2 x 2 x 1/4&quot; &quot;T&quot; BAR</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>3064</td>
<td>30 x 64</td>
<td>32 x 66</td>
<td>1/4&quot;</td>
<td>2 x 2 x 1/4&quot; &quot;T&quot; BAR</td>
<td>93</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE 1**—1 in. = 25.4 mm.
**NOTE 2**—2.2 lb = 1 kg.
**NOTE 3**—For steel doors, see Table 2.
**NOTE 4**—For GRP doors, see Table 3.
**NOTE 5**—Weight does not include fittings.

### TABLE 5 Standard Door Materials

<table>
<thead>
<tr>
<th>Number</th>
<th>Component</th>
<th>Steel Specifications</th>
<th>Aluminum Specification</th>
<th>Glass-Reinforced Plastic (GRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>door panel</td>
<td>A 36/A 36M or A 131/A 131M</td>
<td>B 209</td>
<td>MIL-P-17549, Grade 1 or equivalent</td>
</tr>
<tr>
<td>2</td>
<td>gasket retainer (optional)</td>
<td>not required</td>
<td>not required</td>
<td>not required</td>
</tr>
<tr>
<td>3</td>
<td>gasket</td>
<td>Neoprene 45 Durometer</td>
<td>MIL-R-900</td>
<td>integral</td>
</tr>
<tr>
<td>4</td>
<td>stiffeners</td>
<td>optional</td>
<td>optional</td>
<td>(integral)</td>
</tr>
<tr>
<td>5</td>
<td>door frame</td>
<td>A 36/A 36M or A 131/A 131M</td>
<td>B 209</td>
<td></td>
</tr>
</tbody>
</table>
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the contract or order

S1. Painting

S1.1 Pretreatment and priming of door components shall consist of metal spray coating in accordance with DoD-STD-2138, Type II on both sides before assembly.

S1.2 Aluminum door and components shall be treated with a chemical conversion coating MIL-C-81706, followed with a second coat of epoxy polyamide primer (Formula 150 of MIL-P-24441) alkyd haze gray (TT-E-490 or equal). Coating to be applied before assembly, following surface preparation, in accordance with the manufacturer’s instruction.

S2. Internal Pressure

S2.1 Internal pressure of more than 9 psi (62 kPa) and any other clear openings of door are to be indicated.

S3. Special Heat-Resisting Gaskets

S3.1 Special heat-resisting gaskets in accordance with MIL-G-17927 are to be indicated.

S4. GRP and Aluminum Doors

S4.1 GRP and aluminum doors for 5-psi (34-kPa) internal and 9-psi (62-kPa) external pressures are to be indicated.

S5. Additional Test Requirements

S5.1 Test requirements when indicated, shall allow 1 door out of 50 doors to be tested for 1.5 times the test requirements performed by the manufacturer.

S6. Door Frames

S6.1 Door frames when specified, may be 3- by 2-in. (76- by 50-mm) angles when dogs are located on the doors.

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Standard Specification for
Doors, Non-Tight, for Marine Use

This standard is issued under the fixed designation F 1070; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification to be used in conjunction with Speci-

fication F 1073, covers the principal dimensions and the

mechanical requirements for manufacturing steel, aluminum,

and glass-reinforced plastic non-tight, personnel doors and
dutch doors, with the exception of joiner, joiner dutch doors,

and expanded metal doors, for marine use.

1.2 The doors will be used in non-tight bulkheads.

1.3 When fire protection requirements are applicable to the

location of these doors, then the use of aluminum and glass-

reinforced plastic doors shall be unacceptable.

1.4 The values stated in inch-pound units are to be regarded

as the standard. The values given in parentheses are for

information only.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Carbon Structural Steel 2

A 131/A 131M Specification for Structural Steel for Ships 2

B 209 Specification for Aluminum and Aluminum-Alloy

Sheet and Plate 3

F 1073 Specification for Door Fittings, for Watertight/

Gastight/Airtight, Weathertight, and Non-Tight Doors, for

Marine Use 4

2.2 ABS Standard:

Rules for Building and Classing Steel Vessels 5

2.3 Military Standards:

MIL-P-17549 Plastic Laminates, Fibrous Glass Reinforced,

Marine Structural 6

MIL-R-21607 Resins, Polyester Low-Pressure Laminating,

Fire Retardant 6

MIL-P-24441 Epoxy-Polyamide Paint 6

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships

and Marine Technology and is the direct responsibility of Subcommittee F25.03 on

Outfitting.


3 Annual Book of ASTM Standards, Vol 02.02.

4 Annual Book of ASTM Standards, Vol 01.07.

5 Available from American Bureau of Shipping, ABS Plaza, 16855 Northchase

Dr., Houston, TX 77060.

6 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700

Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

MIL-C-81706 Coating, Aluminum and Aluminum Alloys 6

TT-E-490 Enamel, Silicone Alkyd Copolymer, Semi-gloss,

Exterior 6

DoD-STD-2138 Metal Sprayed Coating Systems for Corro-
sion Protection 6

3. Ordering Information

3.1 Ordering for doors under this specification shall include

the following:

3.1.1 Type of door and material (see Table 1 and Figs. 1-3),

3.1.2 Nominal and ASTM designations,

3.1.3 Quantity, hand of door (right hand or left hand, or

both), and

3.1.4 Optional items, such as fixed lights, door locks, to be

indicated.

3.2 Inspection and acceptance of doors shall be agreed upon

between the purchaser and the supplier.

4. Materials and Manufacture

4.1 The materials and specifications shall be as given in

Table 1.

4.2 Glass-reinforced plastic (GRP) material of doors shall

meet the requirements of MIL-P-17549, Grade 1. In addition,
laminate must have the flammability limits equal to the

requirements for Grade 2, Class A of MIL-R-21607.

5. Construction, Shape, and Dimensions

5.1 The construction, shape, and clear opening dimensions

shall be as shown in Tables 1 and 2 and Figs. 1-3 and conform

to the following requirements:

5.1.1 A right-hand opening door shall be construed as one

that opens towards you with hinges located on right side of

door. A left-hand opening is similar but with hinges on the left.

5.1.2 The size of the door opening and shape shall be as

given in Table 2.

5.1.3 Figs. 1 and 2 show the right-hand opening, and in the
case of left-hand opening, the arrangement of fittings shall be

reversed.

5.1.4 The position of the grab handles shall be located on

the center of the height of both sides of the door; in the case of
dutch doors, the location of the grab handles shall be suitably

positioned in the top panel.
5.1.5 The material of the standard door components shall be as shown in Table 1.

5.1.6 Doors shall be fitted with dogs, hinges, hasp and staple assemblies, grab handles, label plates, and hook assemblies; for details, see Specification F 1073.

5.1.7 Welding shall be done in accordance with the Rules of American Bureau of Shipping.

6. Workmanship, Finish, and Appearance

6.1 All sharp and ragged edges shall be ground flush and removed for personnel protection.

6.2 Pretreatment and priming of door components shall be as follows:
6.2.1 Steel doors and components shall be coated with inorganic zinc-rich primer SSPC Paint 20 Type I-C at 1.5 to 3.0 mil (MDFT), both sides before assembly, following surface preparation in accordance with the manufacturer’s instructions.

6.2.2 Aluminum doors and components are to be pretreated with wash primer coating followed with lead-free, chromate-free, anticorrosion prime coating. Pretreatment and primer are to be applied before assembly, following surface preparation, in accordance with the manufacturer’s instructions.

**FIG. 3 Ships Non-Tight Steel Doors**

**TABLE 1 Standard Door Materials**

<table>
<thead>
<tr>
<th>Number</th>
<th>Component</th>
<th>Mild Steel</th>
<th>Aluminum</th>
<th>Glass-Reinforced Plastic (GRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>door panel</td>
<td>Specifications A 36/A 36M or A 131/A 131M</td>
<td>Specification B 209</td>
<td>MIL-P-17549, Grade 1</td>
</tr>
<tr>
<td>2</td>
<td>stiffeners</td>
<td>Specifications A 36/A 36M or A 131/A 131M</td>
<td>Specification B 209</td>
<td>integral</td>
</tr>
</tbody>
</table>

**TABLE 2 Door—Non-Tight**

<table>
<thead>
<tr>
<th>Nominal No.</th>
<th>Size of Opening</th>
<th>Door</th>
<th>Calculated Mass, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Width</td>
<td>Height</td>
<td>W</td>
</tr>
<tr>
<td>2654</td>
<td>26</td>
<td>54</td>
<td>55</td>
</tr>
<tr>
<td>2666</td>
<td>26</td>
<td>66</td>
<td>67</td>
</tr>
<tr>
<td>3060</td>
<td>30</td>
<td>63</td>
<td>64</td>
</tr>
<tr>
<td>3063</td>
<td>30</td>
<td>63</td>
<td>64</td>
</tr>
<tr>
<td>3066</td>
<td>30</td>
<td>66</td>
<td>67</td>
</tr>
</tbody>
</table>

**Note:**
- 1 in. = 25.4 mm.
6.2.3 GRP doors and components are to have color tint “haze gray” painted upon completion of the molding process.

7. Product Marking

7.1 Each door shall be marked with the purchase order number by attaching a CRES label plate to the door panel using letters at least ½ in. (12.7 mm) high, indicating the ASTM designation number, nominal number, thickness of door plate, and direction of opening. Other markings may be in paint.

7.2 Label plates shall be screwed or bolted to the door panel on steel and aluminum doors.

7.3 GRP door label plates shall be affixed to the door with epoxy.

8. Packaging and Package Marking

8.1 Doors shall be crated or attached to a pallet in a manner acceptable for shipment by a common carrier. The door and door frame assembly shall be shipped as one unit, with gasket protected from knife edge by an inserted partition.

9. Keywords

9.1 doors; dutch doors; marine; non-tight doors; personnel doors; ship

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the contract or order.

S1. Pretreatment and Priming of Door Components

S1.1 Pretreatment and priming of door components shall consist of metal spray coating in accordance with DoD-STD-2138, Type II, on both sides before assembly.

S2. Aluminum Doors and Components

S2.1 Aluminum doors and components shall be treated with a chemical conversion coating MIL-C-81706, followed with a second coat of epoxy polyamide primer (Formula 150 of MIL-P-24441) alkyd haze gray (TT-E-490 or equal). Coating to be applied before assembly, following surface preparation, in accordance with the manufacturer’s instruction.
1. Scope

1.1 This specification covers steel expanded-metal bulkhead panels suitable for use in storerooms, shops, and as protection against personnel hazards.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
   A 36/A 36M Specification for Carbon Structural Steel
   D 3951 Practice for Commercial Packaging

2.2 Other Documents:
   ABS Rules for Building and Classing Steel Vessels
   AWS D1.1 Structural Welding Code

3. Classification

3.1 Bulkhead panels are furnished in three types as follows.
   3.1.1 Type I—Universal bulkhead panels for use as either a right-hand or left-hand panel.
   3.1.2 Type II—Right-hand bulkhead panel.
   3.1.3 Type III—Left-hand bulkhead panel.

3.2 Bulkhead panels are furnished in two classes as follows.
   3.2.1 Class A—Bulkhead panels, 2 ft (610 cm).
   3.2.2 Class B—Bulkhead panels, 3 ft (915 cm).

3.3 Bulkhead panels Types II and III, Class A only, are furnished in three sizes as follows.
   3.3.1 Size 1—76 in. (195 cm) high.
   3.3.2 Size 2—64 in. (165 cm) high.
   3.3.3 Size 3—40 in. (100 cm) high.

4. Ordering Information

4.1 Orders for expanded-metal panels under this specification shall include this specification number, type, class, and size.

5. Materials and Manufacture

5.1 Materials:

5.2 Manufacture:
   5.2.1 Welding shall be in accordance with AWS D1.1 or the ABS Rules for Building and Classing Steel Vessels.
   5.2.2 Panels shall be welded and fabricated as shown in Figs. 1-6.
   5.2.3 After panels have been shipped to the contractor, the panels will be assembled into bulkheads by welding or bolting by others.

6. Tolerances

6.1 Tolerances—±1/16 in. (1.5 mm).

7. Workmanship, Finish, and Appearance

7.1 Expanded-metal panels shall be free from all cracks, burrs, sharp edges, and other defects.

7.2 The panel manufacturer shall apply a nonhazardous corrosion-inhibiting primer coating to all panel assemblies.

8. Packaging and Package Marking

8.1 Expanded-metal bulkhead panels shall be individually packed for shipment and storage in accordance with Practice D 3951.

8.2 In addition to any special marking required by the contract or purchase order, each expanded-metal panel package shall be marked in accordance with Practice D 3951.

9. Keywords

9.1 bulkhead panels; expanded-metal bulkhead panels; panels; steel bulkhead panels
### TABLE 1  Expanded-Metal Bulkhead Panel Materials

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame angle, 1¼ × 1¼ × ¼ in., Specification A 36/A 36M</td>
</tr>
<tr>
<td>2</td>
<td>Brace flatbar, ¼ × 2 in., Specification A 36/A 36M</td>
</tr>
<tr>
<td>3</td>
<td>Expanded metal 13-gage thick × ½-in. flat pattern × 23 in. wide, Specification A 36/A 36M</td>
</tr>
<tr>
<td>4</td>
<td>Expanded metal 13-gage thick × ½-in. flat pattern × 35 in. wide, Specification A 36/A 36M</td>
</tr>
</tbody>
</table>

**FIG. 1** Expanded-Metal Bulkhead Panel—Type 1, Class A, Size 1

Note 1—1 in. = 25.4 mm.
**FIG. 2 Expanded-Metal Bulkhead Panel—Type I, Class B, Size 1**

*Note 1—1 in. = 25.4 mm.*

**FIG. 3 Expanded-Metal Bulkhead Panel—Type II, Class A, Size 1**

*Note 1—Type III—Left hand not shown.
Note 2—1 in. = 25.4 mm.*

**FIG. 4 Expanded-Metal Bulkhead Panel—Type II, Class B, Size 1**

*Note 1—Type III—Left hand not shown.
Note 2—1 in. = 25.4 mm.*
FIG. 5 Expanded-Metal Bulkhead Panel—Type II, Class A, Size 2

FIG. 6 Expanded-Metal Bulkhead Panel—Type II, Class A, Size 3

NOTE 1—1 in. = 25.4 mm.
1. Scope

1.1 This specification covers steel expanded-metal doors suitable for installation in expanded-metal bulkheads, structural bulkheads, and structural arches.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
   A 36/A 36M Specification for Carbon Structural Steel
   A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
   D 3951 Practice for Commercial Packaging
   F 783 Specification for Staple, Handgrab, Handle, and Stirrup Rung

2.2 Other Documents:
   ABS Rules for Building and Classing Steel Vessels
   AWS D1.1 Structural Welding Code

3. Classification

3.1 Expanded-metal doors are furnished in four types (see Detail “J”) as follows:
   3.1.1 Type I—Right hand (RH).
   3.1.2 Type II—Left hand (LH).
   3.1.3 Type III—Right hand reverse (RHR).
   3.1.4 Type IV—Left hand reverse (LHR).

4. Ordering Information

4.1 Orders for doors under this specification shall include the classification and type.

5. Materials and Manufacture

5.1 Materials—See Table 1.
5.2 Manufacture:
   5.2.1 Doors shall be furnished with the vertical support channels and top angle in place. A temporary brace shall be included at the frame bottom to prevent racking.
   5.2.2 Welding shall be in accordance with AWS D1.1 Structural Welding Code or ABS Rules for Building and Classing Steel Vessels.

6. Installation Requirements

6.1 Doors shall be fitted with rubber-tipped bumpers and a manually operated catch for holding doors in an open position. These shall be furnished and installed by others.

6.2 Provision shall be made for the installation of a rim latch set operated by knobs on both sides. This hardware shall be furnished and installed by others.

6.3 Padlocks shall be furnished by others.

6.4 Any holes needed in the frame for installation in expanded-metal or other types of bulkheads shall be made at installation by others.

7. Dimensions and Tolerances

7.1 Dimensions are as indicated in Figs. 1-8 and Table 1.
7.2 Tolerance—± 1/16 in. (1.5 mm).

8. Workmanship, Finish, and Appearance

8.1 Doors and frames shall be free from all cracks, burrs, sharp edges, and other defects.

8.2 The door manufacturer shall apply a nonhazardous corrosion-inhibiting primer coating to all door assemblies.

9. Packaging and Package Marking

9.1 Each expanded-metal door shall be individually packed for shipment and storage in accordance with Practice D 3951.

9.2 In addition to any special marking required by the contract or purchase order, each expanded-metal door shall be marked in accordance with Practice D 3951.

10. Keywords

10.1 expanded-metal doors; expanded-metal bulkheads; metal doors; structural arches; structural bulkheads
TABLE 1 Expanded-Metal Door Materials

Note 1—1 in. = 25.4 mm.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame Top—Angle, 6 × 3½ × ¼ in., Specification A 36/A 36M.</td>
</tr>
<tr>
<td>2</td>
<td>Frame Side—Channel, C3 × 5.0, Specification A 36/A 36M.</td>
</tr>
<tr>
<td>3</td>
<td>Staple—Round bar, Specification F 783.</td>
</tr>
<tr>
<td>4</td>
<td>Door Frame—Angle, 1¼ × 1¼ × ¼ in., Specification A 36/A 36M.</td>
</tr>
<tr>
<td>5</td>
<td>Brace—Flat bar, 2 × ¼ in., Specification A 36/A 36M.</td>
</tr>
<tr>
<td>6</td>
<td>Cross Brace—Flat bar, 2 × ¼ in., Specification A 36/A 36M.</td>
</tr>
<tr>
<td>7</td>
<td>Stop—Flat bar, 4 × ¼ in., Specification A 36/A 36M.</td>
</tr>
<tr>
<td>8</td>
<td>Pad—Flat bar, 4 × ¼ in., Specification A 36/A 36M.</td>
</tr>
<tr>
<td>9</td>
<td>Hinge—Swaged butt, plain, fixed pin, 3- × 2½-in. Type 316 stainless steel, Specification A 167.</td>
</tr>
<tr>
<td>10</td>
<td>Expanded Metal—13-gage × ½-in. flat pattern, Specification A 36/A 36M.</td>
</tr>
<tr>
<td>11</td>
<td>Temporary Brace—Angle 1¼ × 1¼ × ¼ in., Specification A 36/A 36M. (See 5.2.1.)</td>
</tr>
</tbody>
</table>
FIG. 1 Right-Hand Door and Frame Assembly—Type I (Left Hand, Type II Not Shown)

Note 1—1 in. = 25.4 mm.
FIG. 2 Right-Hand Reverse Door and Frame Assembly—Type III (Left Hand, Type IV Not Shown)

NOTE 1—1 in. = 25.4 mm.
FIG. 3 Frame

Note 1—1 in. = 25.4 mm.

FIG. 4 Door

Note 1—1 in. = 25.4 mm.
FIG. 5 Pad

FIG. 6 Stop

FIG. 7 Brace and Cross Brace
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FIG. 8 Installation Details

Note: 1 in. = 25.4 mm.
Standard Specification for Door Fittings, for Watertight /Gastight /Airtight, Weathertight, and Non-Tight Doors, for Marine Use

This standard is issued under the fixed designation F 1073; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the principal design and type of material for manufacturing fittings for watertight/gastight/airtight, weathertight, and non-tight doors, for marine use. Note that “gastight” is commercial terminology which also means “airtight” in naval terminology.

1.2 The fittings are intended for use on all doors for marine use, except joiner and expanded metal doors.

2. Referenced Documents

2.1 ASTM Standards:

- A 36/A36M Specification for Carbon Structural Steel
- A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
- A 276 Specification for Stainless and Heat-Resisting Steel Bars and Shapes
- A 563 Specification for Carbon and Alloy Steel Nuts
- A 668 Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use
- B 140/B 140M Specification for Copper-Zinc-Lead Red Brass or Hardware Bronze Rod, Bar and Shapes
- B 210 Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes

2.2 Military Standards:

- MIL-P-24441 Epoxy-Polyamide Paint
- MIL-P-17578A Packing Material, Plastic (for Dogs for Watertight Closures) (Symbol 1425)
- MIL-C-81706 Coating, Aluminum and Aluminum Alloys
- DOD-STD-2138 Metal Sprayed Coating Systems for Corrosion Protection

2.3 Federal Specifications:

- QQ-C-390 Copper Alloy Castings
- TT-E-490 Enamel-Silicone Alkyd Copolymer, Semi-gloss, Exterior

2.4 ANSI Standard:

- A2.6 Standard for Fire Tests of Window Assemblies

2.5 AISI Standard:

- 316 Low Alloy Stainless Steel (Cres 316)

3. Classification

3.1 The dogs and hinges shall be classified as given in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog:</td>
<td>Fitted to door</td>
</tr>
<tr>
<td>A</td>
<td>Fitted to door frame</td>
</tr>
<tr>
<td>B</td>
<td>With clenched pin</td>
</tr>
<tr>
<td>Hinge:</td>
<td>With clenched pin secured with cotter pin</td>
</tr>
</tbody>
</table>

4. Ordering Information

4.1 Ordering for fittings shall be indicated on the purchase order prepared for doors, with reference to this specification noted.

4.2 When ordering fittings, indicate the following:

- 4.2.1 Type,
- 4.2.2 Quantity,
- 4.2.3 Marking (see Section 8), and
- 4.3 Inspection and acceptance of fittings shall be agreed upon between the purchaser and the supplier.

5. Materials and Manufacture

5.1 The material shall be as specified in Tables 2-4.

5.2 All securing screws and fasteners shall be of stainless steel, Type 316.
5.3 All glazing in portlights of fire door shall meet ANSI A2.6.

6. Construction, Shape, and Dimensions

6.1 The construction, shape, and dimensions for dogs and hinges shall be as shown in Figs. 1-9.

6.2 Door dogs shall be supplied with hold-open clips.

7. Workmanship, Finish, and Appearance

7.1 All materials shall have a smooth finish.

7.2 Pretreatment and priming of door fittings shall be as follows:

7.2.1 Mild steel fittings shall be abrasive blasted to “near white” metal and coated with inorganic zinc silicate at 1.5 to 3.0 mils.

7.2.2 Steel fittings, secured on doors, shall be welded to steel; whereas aluminum fittings when secured to aluminum or glass-reinforced plastic doors, shall be welded or bolted into position.

7.2.3 Nonferrous fittings shall be either riveted or bolted to aluminum, steel or glass-reinforced plastic doors, or combination thereof.

7.2.4 Where different metals are to be used, insulation shall be used between them, in way of contact, to prevent galvanic action.

8. Product Marking

8.1 Each fitting shall be marked with its purchase order number and shall indicate the type of fitting, left hand or right hand. The marking shall be applied on a waterproof tag and attached to the fitting.

9. Keywords

9.1 airtight; door fittings; doors; gastight; marine; non-tight; ship; tightness integrity; watertight; weathertight
FIG. 1 Watertight, Airtight, and Weathertight Door Dog Assembly (Estimated Weight 8 lb)

FIG. 2 Dog Details
FIG. 3 Dog Assembly for Non-Tight Doors (Estimated Weight 8 lb)
FIG. 4 Hinge Assembly for Non-Tight Doors

Note—1 in. = 25.4 mm.
2.2 lb = 1 kg.

FIG. 5 Hook Staple Detail

Note—1 in. = 25.4 mm.

FIG. 6 Grabhandle Detail

Note—1 in. = 25.4 mm.
NOTE — 1 in. = 25.4 mm.

FIG. 7 Frame Assembly Fixed Light

NOTE — 1 in. = 25.4 mm.

FIG. 8 Hasp and Eye Assembly “A”
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the contract or order.

S1. Painting

S1.1 Pretreatment and priming of mild steel door components shall consist of metal spray coating in accordance with DOD-STD-2138, Type II on both sides before assembly.

S1.2 Aluminum door components shall be treated with a chemical conversion coating MIL-C-81706, followed with a second coat of epoxy polyamide primer (formula 150 of MIL-P-24441) alkyd haze gray (TT-E-490) or equal. Coating to be applied before assembly, following surface preparation, in accordance with the manufacturer’s instructions.

S1.3 Special heat resisting gaskets, in accordance with MIL-P-17578A, are to be used.

NOTE — 1 in. = 25.4 mm.

FIG. 9 Hinge Assembly for Aluminum Doors
Standard Specification for Cleats, Welded Horn Type

This standard is issued under the fixed designation F 1074; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers hollow cleats and pads for marine use.

1.2 The cleats shall be used where securing of boat handling lines are required onboard commercial and navy boats and crafts.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Carbon Structural Steel

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip)

3. Ordering Information

3.1 Orders for material under this specification shall include the following:

3.1.1 Title, number, and date of this specification,

3.1.2 Quantity,

3.1.3 Size of cleats, and

3.1.4 Packaging, packing, or marking requirements.

4. Materials and Manufacture

4.1 Material:

4.1.1 The horn cleats shall be of galvanized steel, grade 1023W, in accordance with Practice A 385.

4.1.2 The base plate shall be of steel, (carbon 0.35 maximum), in accordance with Specification A 36/A 36M.

4.1.3 All chafing surfaces shall have a 125µ finish.

4.2 Manufacture—The cleats’ horns shall be of cast steel, round in shape, and free of burrs or sharp edges. The horns shall be welded to a base plate as shown in Fig. 1 (see Table 1). The weld is to be ground smooth to prevent chafing of ropes. The base plate shall be oval shaped with smooth rounded edges. The dimensions shall be in accordance with Table 1.

5. Packaging

5.1 The packing shall afford protection against deterioration and physical damage during shipment from the manufacturer to the using activity for immediate use.

6. Product Marking

6.1 Containers shall be stenciled with the ASTM standard designation, in black paint with approximately 1 in. (25.4 mm) high letters and numbers with the following information:

6.1.1 Address,

6.1.2 purchase order number, and

6.1.3 Manufacturer’s name.

7. Keywords

7.1 base plates; boat handling lines; cleats; hollow cleats; horn cleats; marine; marine cleats; ship; welded cleats

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.


3 Annual Book of ASTM Standards, Vol 01.03.

4 Annual Book of ASTM Standards, Vol 01.06.
FIG. 1 Welded Horn Type Cleat (16 in.)

Note—See Table 1 for dimensions.
TABLE 1 Welded Horn-Type Cleat Dimensions

<table>
<thead>
<tr>
<th>Cleat Dimensions (in.)</th>
<th>Calculated Weight (lb)</th>
<th>Rope Circumference (in.)</th>
<th>Rope Diameter (in.)</th>
<th>Test Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Manilla</td>
<td>Nylon</td>
<td>Dacron</td>
</tr>
<tr>
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<td></td>
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<tr>
<td>10 2 1/2 3 1/4 1/4 1 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8</td>
<td>5.3</td>
<td>1 1 1 1/8</td>
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<td>16 4 3 5 2 1 1/4 1 1/4 3 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 21.7</td>
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<td></td>
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<td>5 3 3 4</td>
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<td>6 3 1/4 4</td>
<td>36000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1—Table 1 is to be used with Fig. 1.
NOTE 2—1 in. = 25.4 mm.
NOTE 3—1 lb = 0.45 kg.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the contract or order.


S1.1 Responsibility for Inspection—The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

S1.2 Source Inspection—The purchaser reserves the right to inspect the manufacturing process and end product in the supplier’s plant.

S1.3 Tests—The cleats shall meet the test load requirements of Table 1, as tested in accordance with Test Methods and Definitions A 370.
Standard Specification for
Dehumidifier, Shipboard, Mechanically Refrigerated, Self-Contained

1. Scope
1.1 This specification covers self-contained dehumidifiers using hermetic refrigerant motor-compressors.
1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.
1.3 The following safety hazards caveat pertains only to the test methods portion, Section 11, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents
2.1 ASTM Standards:
   B 117 Practice for Operating Salt Spray (Fog) Apparatus
   B 280 Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
   D 1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
   D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
2.2 ASHRAE Standard—15 Safety Code for Mechanical Refrigeration
2.3 Official Classification Standard:
   MIL-S-901 Specification Requirements for Shock Tests, High Impact (H.I.); Shipboard Machinery, Equipment, and Systems
   MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment, (Type I—Environmental and Type II—Internally Excited)
   MIL-D-19947 Specification for Dehumidifier, Space, Mechanically Refrigerated, Self-Contained, Naval Shipboard

3. Ordering Information
3.1 Orders for products under this specification shall include the following information, as necessary, to describe adequately the desired product:
   3.1.1 Title, ASTM designation, and year of issue,
   3.1.2 Quantity (number of dehumidifiers),
   3.1.3 Certification if required, and
   3.1.4 Additions to the specification and supplementary requirements, if required.

4. Materials and Manufacture
4.1 In addition to the requirements cited in this specification, the dehumidifiers covered by this specification shall be designed, constructed, assembled, and tested to comply with UL 474, UL 984, and ASHRAE Standard 15. In the event of differences between any of the requirements of this specification and those of other referenced documents, the requirements of this specification shall govern. The manufacturer shall certify compliance with the above standards for equipment furnished and shall be cited in the UL Electrical Appliance and Utilization Equipment product directories.

4.2 The dehumidifier shall consist of a motor-compressor, condensing unit, dehumidifying coil, air-circulating fan, and accessories, all enclosed within a metal cabinet. The dehumidifier shall be complete, self-contained with the refrigeration

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1 Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.
2 Available from Uniform Classification Agent, Tariff Publication Officer, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.

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5 Available from Underwriter’s Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.
equipment dehydrated, and charged with the necessary operating quantity of refrigerant and oil. Each unit shall be ready for operation after removal of shipping protection, opening of valves where provided, and connection to electric power.

4.3 The motor-compressor shall be of the hermetic type and shall consist of a compressor and motor enclosed in a gastight shell. The hermetic compressor unit shall conform to UL 984 and shall be at least 3/4 hp. Equipment shall operate on 115-V, single-phase, 60-cycle alternating current. The unit shall be protected against overload by a thermal protector built into the motor. The thermal protection shall be either the manual or automatic reset type.

4.4 Piping necessary for the satisfactory operation of the equipment shall be provided by the manufacturer. Tubing shall be made of copper in accordance with Specification B 280. Piping connections shall be arranged in such a manner so as not to impair the vibration-isolation properties of absorption-type mounts, where such mounts are provided. Piping shall be securely supported to minimize strain and vibration. Piping connections shall not be made of soft solder.

4.5 Materials used in the manufacture of the equipment shall be corrosion-resistant or treated to resist corrosion. The method of manufacture shall not impair physical, structural, or corrosion-resistant properties of the components. Materials, coatings, and paint systems shall satisfactorily pass the applicable salt spray and humidity test specified in this specification.

4.6 Bolts, nuts, studs, pins, screws, and such other fastenings or fittings shall be of a corrosion-resistant material, or of a material treated in a manner to render it adequately resistant to corrosion. Screws exposed in final assembly shall be corrosion-resistant material.

4.7 Similar parts, including repair parts, or corresponding apparatus furnished on the same contract or order, or built to the same drawings, shall be strictly interchangeable without the necessity of further machining or hand fitting of any kind.

4.8 A plastic or other chemically inert container shall be provided for collecting the condensate. The container shall be of a size and configuration that will fit within the cabinet enclosure. The container shall be provided with baffles to prevent the overflow or spilling of water and shall be readily removable from the dehumidifier cabinet. A male fitting shall be provided from the container for connection of a 0.375-in. (10-mm) inside diameter flexible rubber tubing for draining the condensate (wall thickness 0.125 in. (3 mm)). The rubber tubing will not be required to be furnished by the contractor.

4.9 Provision shall be made in the frame to permit securing the cabinet to any appropriate surface.

4.10 Identification plates shall be of a nonferrous metal or corrosion-resistant steel and shall conform to UL 474.

5. Performance Requirements

5.1 The unit shall be capable of condensing at least 1.8 gal (7 L) of water in 24 h at an ambient temperature of 90°F (32°C) dry bulb and 60% relative humidity.

5.2 The unit shall operate satisfactorily in a maximum ambient temperature of 110°F (43°C) and a minimum relative humidity of 30%. Under these conditions of maximal load, the temperature rise of the hermetic motor shall not exceed 158°F (70°C).

5.3 The equipment shall operate satisfactorily when inclined at an angle of 15° on each side of the vertical, in each of two vertical planes at right angles to each other.

6. Other Requirements

6.1 Design Documentation—A master drawing of a built configuration shall be provided for each of the following:

6.1.1 Complete dehumidifier,

6.1.2 Motor compressor,

6.1.3 Condenser, and

6.1.4 Fan and cooling coil.

6.1.5 Each master drawing shall show outline, mounting, attachment, and connection dimensions, including methods and sizes of fastenings and clearances for installation and servicing, plus supplementary data as necessary to permit installation without suppliers assistance. The drawing shall illustrate design, construction, operation (or function), and identity of parts. Where acceptance tests are required, the tests shall be identified, and approval authority and date shall be noted on the drawing. Subassembly drawings shall be provided to supplement master drawings where desirable.

6.2 Schematic Drawings:

6.2.1 Schematic drawings shall be provided that include all mechanical, piping and electrical circuits, and connections.

6.2.2 All symbols used for equipment components or parts shall be given a piece number and identified in the list of materials with the following information:

6.2.2.1 Piece number,

6.2.2.2 Quantity required,

6.2.2.3 Descriptive name,

6.2.2.4 Manufacturer,

6.2.2.5 Manufacturer’s model or identifying number,

6.2.2.6 Manufacturer’s drawing number, and

6.2.2.7 Weight.

6.3 Manuals—Manuals shall be typed in accordance with the manufacturer’s commercial practice. Photo views of the equipment shall be included as part of the general description. A section shall be provided containing reduced copies of all drawings required to amplify or illustrate the text including diagram and assembly drawings.

7. Workmanship, Finish, and Appearance

7.1 All materials forming a part of the finished product shall be new and suitable for the purpose intended. The materials shall be free from any defects that might affect the serviceability or appearance of the finished product.

7.2 Seal caps in the refrigerant system shall be provided with a gasket and shall be tight against any leaks.

7.3 Bolts, nuts, and screws shall be tight and equipment and parts shall be properly fastened and secured.

7.4 No parts or components shall be fractured, split, torn, dented, or otherwise defective.

7.5 The limiting and mounting dimensions shall be in accordance with the drawings.

7.6 There shall be no sharp or ragged edges that may be injurious to people.
8. Sampling

8.1 Sample units shall be selected from each lot offered for delivery, in accordance with Table 1 and subjected to the tests specified in 8.3.

8.2 If any unit fails in any test or is found nonconforming in any requirement, it shall be counted a defective unit, and if the number of such defective units in any sample exceeds the acceptance number shown in Table 1 for the sample, the lot represented by the sample will be rejected.

8.3 Quality Conformance Tests:

8.3.1 The units shall be operated for a period of at least 1 h under ambient atmosphere conditions. During the test, all refrigerant containing parts shall be leak tested by means of a halide leak detector and shall be free of any leaks. In the evidence of leakage, the unit shall be considered defective. The halogen leak detector shall have a leak index sensitivity of 1/2 oz per year (14 g per year).

8.3.2 Under equivalent ambient temperature, the electrical power input shall be measured and compared with the input of all other units that have been tested. If any unit requires 7% more power than the average of all the acceptable units, it shall be counted as a defective unit and shall only be offered for delivery after the cause has been found and corrected.

9. Number of Tests and Retests

9.1 A first unit shall satisfactorily pass the tests listed in 11.1-11.3 before production units are offered for delivery.

9.2 A test for the corrosion-resistant properties of the materials, coating, and painting system used, shall be carried out as specified in 11.4.

10. Specimen Preparation

10.1 Test specimens for the corrosion test shall be prepared by the manufacturer as required, and shall be of the same material used in the dehumidifier. The film thickness of the coating or paint system applied on the test specimen shall be the same as the film thickness used on the equipment.

11. Test Methods

11.1 Design Capacity Test—Install the unit in an ambient temperature of 90°F (32°C) and 60% relative humidity. Operate the unit for a period of 4 h. Under these conditions, the unit shall condense moisture at the rate of at least 1.8 gal (7 L) of water in 24 h. Record ambient temperature, relative humidity, and quantity of condensate at 20-min intervals.

11.2 Overload Test—Install the unit in an ambient temperature of 110°F (43°C) and not less than 30% relative humidity. The unit shall operate without tripping the compressor motor overload device or without breakdown. Continue the test until steady conditions have been observed for at least 4 h. Record ambient temperature, relative humidity, and voltage at service connection every 20 min. Determine the temperature of the compressor-motor winding at the end of the 4-h test period. The temperature rise shall not exceed 158°F (70°C). Measure and compute the temperature rise of the running winding in the compressor-motor by the resistance method.

11.3 Inclination Test—Incline the unit at an angle of 15° on each side of the vertical in each of two vertical planes at right angles to each other and operate at least 1 h in each plane with no abnormal variations in temperature. Collect and drain condensate from the evaporator into the container without any spillage in any of the inclined positions.

11.4 Corrosion Resistant Test—Test the test specimens in a corrosion environment in accordance with Practice B 117 (Salt Spray Apparatus) and Practice D 2247 (100% relative humidity test). The time duration of each test shall be 240 h. Evaluate the test specimens in accordance with Test Method D 1654. The rating number shall not be less than 6, and the rust creep shall not be greater than 1/8 in. (3 mm) normal to the scribe marks for acceptance.

12. Inspection

12.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to the prescribed requirements.

13. Rejection

13.1 Material that fails to conform to the requirements of this specification when inspected or tested by the purchaser or his agent may be rejected.

14. Certification

14.1 When specified in the purchase order or contract, a manufacturer’s or supplier’s certification shall be furnished to the purchaser stating that the equipment was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, drawings shall be provided that are sufficiently complete to reflect compliance with specification requirements for the equipment, and a report of the test results shall be furnished.

15. Packaging and Package Marking

15.1 Preservation and Packaging—Preservation and packaging shall be sufficient to afford adequate protection against
corrosion, deterioration, and physical damage during shipment from the supply source to the using activity and until installation and may conform to the suppliers commercial practice when such meets these requirements. Manuals furnished with basic equipment shall be packaged in sealed, waterproof containers.

15.2 **Packing**—Packing shall be accomplished in a manner that will ensure acceptance by common carrier at the lowest rate and will afford protection against physical or mechanical damage during direct shipment from the supply source to the using activity for early installation. The shipping containers or method of packing shall conform to the Uniform Freight Classification Rules and Regulations or other carrier regulations as applicable to the mode of transportation and may conform to the suppliers commercial practice when such meets these requirements.

**SUPPLEMENTARY REQUIREMENTS**

The following supplementary requirements are applicable to DoD procurements and shall apply only when specified by the purchaser in the contract or order.

**S1. Dimensions, Mass, and Permissible Variations**

**S1.1** **Size**—The unit shall permit passing through a circular opening 21 in. (530 mm) in diameter and a rectangular opening 18 by 30 in. (460 by 760 mm).

**S2. Design Requirements**

**S2.1** **Shock**—The dehumidifier shall be designed to meet shock requirements in accordance with MIL-S-901, for Grade B equipment.

**S2.2** **Vibration**—The dehumidifier shall be designed to withstand conditions in accordance with MIL-STD-167-1 for Type I and Type II vibration of shipboard equipment.

**S3. First Article Testing**

S3.1 A first unit shall satisfactorily pass the tests listed in S3.2 and S3.3 before production units are offered for delivery.

**S3.2** **Shock Testing**—A first unit shall be subjected to and shall meet Grade B shock requirements in accordance with MIL-S-901.

**S3.3** **Vibration Testing**—A first unit shall be subjected to and shall withstand vibration testing in accordance with MIL-STD-167-1 for Type I and Type II equipment.

**S4. First Article Test Report**

S4.1 A first article test report shall be submitted certifying compliance with the requirements specified in this specification.
Standard Practice for
Expanded Welded and Silver Brazed Socket Joints for Pipe
and Tube

This standard is issued under the fixed designation F 1076; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers expanded welded and silver brazed
socket joints for use on shipboard piping systems.

1.2 Expanded welded and silver brazed socket joints are to
be used to join two pipes or tubes having the same NPS (see
Note 1) without using a fitting or butt weld.

1.3 Brazed socket type joints are not intended for use on
systems containing flammable or combustible fluids in areas
where fire hazards exist or where the service temperature
exceeds 425°F (205°C).

1.4 Brazed joints depending solely upon a fillet weld rather
than primarily upon brazing material between pipe/tube and
socket are not covered by this practice.

Note 1—The dimensionless designator nominal pipe size (NPS) has
been substituted in this practice for such traditional terms as “nominal
diameter,” “size,” “nominal size,” and “iron pipe size.”

1.5 The values stated in inch-pound units are to be regarded
as the standard.

1.6 This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
priate safety and health practices and determine the applica-
ibility of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards: 2
   A 312/A 312M Specification for Seamless and Welded Aus-
   tenitic Stainless Steel Pipes
   B 75 Specification for Seamless Copper Tube
   B 88 Specification for Seamless Copper Water Tube
   B 466/B 466M Specification for Seamless Copper-Nickel
   Pipe and Tube
   2.2 Military Standards: 3

MIL-P-1144 Pipe, Corrosion-Resistant, Stainless Steel,
Seamless and Welded
MIL-T-16420 Tube, Copper-Nickel Alloy, Seamless and
Welded
MIL-T-24107 Tube, Copper (Seamless)
2.3 ASME Standard: 4
ASME Boiler Code
2.4 Federal Standard: 3
Title 46 Code of Federal Regulations
2.5 NAVSEA Document: 3
0900-LP-001-7000 Fabrication and Inspection of Brazed
Piping Systems

3. Significance and Use

3.1 Expanded welded socket joints may be used with the
following pipe and tube:

   3.1.1 Seamless Copper Tube—2.375-in. (60-mm) outside
diameter through 6.625-in. (170-mm) outside diameter.
   3.1.2 Seamless Copper-Nickel Tube—2.375-in. (60-mm)
outside diameter through 6.625-in. (170-mm) outside diameter.
   3.1.3 Seamless Copper Water Tube—2.125-in. (55-mm)
outside diameter through 4.125-in. (105-mm) outside diameter.
   3.1.4 Seamless Stainless Steel Pipe—2 NPS through 6 NPS,
Schedules 5 and 10.

3.2 Expanded silver brazed socket joints may be used with
the following pipe and tube:

   3.2.1 Seamless Copper Tube—2.375-in. (60-mm) outside
diameter through 6.625-in. (170-mm) outside diameter.
   3.2.2 Seamless Copper-Nickel Tube—2.375-in. (60-mm)
outside diameter through 6.625-in. (170-mm) outside diameter.
   3.2.3 Seamless Copper Water Tube—2.125-in. (55-mm)
outside diameter through 4.125-in. (105-mm) outside diameter.

3.3 Expanded welded and silver brazed socket joints may be
used where experience or test has demonstrated that the joint is
safe and suitable for design and operating conditions, and
where adequate provision is made to prevent separation of the
joint.

4. Materials and Manufacture

4.1 Welded Socket Joint:

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1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and
Marine Technology and is the direct responsibility of Subcommittee F25.11 on
Machinery and Piping Systems.


2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or
contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM
Standards volume information, refer to the standard’s Document Summary page on
the ASTM website.


4 Available from American Society of Mechanical Engineers (ASME), ASME
International Headquarters, Three Park Ave., New York, NY 10016-5990.
4.1.1 Seamless Copper Tube—Specification B 75, UNS Number C12200 and MIL-T-24107, UNS Number C12200, light drawn (see 5.3).

4.1.2 Seamless Copper-Nickel Tube (90-10)—Specification B 466/B 466M, UNS Number C70600 and MIL-T-16420, UNS Number C71500, Class 200, annealed.

4.1.3 Seamless Copper-Nickel Tube (70-30)—Specification B 466/B 466M, UNS Number C71500 and MIL-T-16420, UNS Number C71500, Class 200, annealed.

4.1.4 Seamless Copper Water Tube—Specification B 88, Type K, UNS Number C71500, drawn (see 5.3).

4.1.5 Seamless Stainless Steel Pipe—Specification A 312/A 312M, UNS Number S30400 and S31600. MIL-P-1144, UNS Number S30400 and S31600, Schedules 5 and 10.

4.2 Silver-Brazed Socket Joint:

4.2.1 Seamless Copper Tube—Specification B 75, UNS Number C12200 and MIL-T-24107, UNS Number C12200, light drawn (see 5.3).

4.2.2 Seamless Copper-Nickel Tube (90-10)—Specification B 466/B 466M, UNS Number C70600 and MIL-T-16420, UNS Number C71500, Class 200, annealed.

4.2.3 Seamless Copper-Nickel Tube (70-30)—Specification B 466/B 466M, UNS Number C71500 and MIL-T-16420, UNS Number C71500, Class 200, annealed.

4.2.4 Seamless Copper Water Tube—Specification B 88, Type K, UNS Number C12200, drawn (see 5.3).

<table>
<thead>
<tr>
<th>TABLE 1 Expanded Welded Socket Joint</th>
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<tbody>
<tr>
<td><strong>Material</strong></td>
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<td>Seamless light drawn copper tube, Specification B 75, UNS Number C12200 and MIL-T-24107, Alloy 122,</td>
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<td>Seamless annealed copper-nickel tubing (90-10), Specification B 466/B 466M, UNS Number C70600 and MIL-T-16420, Alloy 706, Class 200,</td>
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<tr>
<td>Seamless stainless steel pipe, Specification A 312/A 312M, UNS Number S30400 and S31600, MIL-P-1144, Alloy 304 and 316, Schedule 10,</td>
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<td>Seamless light drawn copper tube, Specification B 75, UNS Number C12200 and MIL-T-24107, Alloy 122,</td>
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Note: 1—1 in. = 25.4 mm. °F = (°C × 9/5) + 32.
TABLE 1  Continued

<table>
<thead>
<tr>
<th>Material</th>
<th>System Size</th>
<th>Wall Thickness</th>
<th>Maximum Design Pressure and Temperature</th>
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</tbody>
</table>

\(^2\) See 5.3.

5. Procedure

5.1 Install no more than two expanded joints in any 36-in. (915-mm) long section of pipe/tube and in no case allow a pipe/tube expanded at both ends in lengths of less than 36 in.

5.2 Fabricate expanded joints on the ends of the pipe/tube by use of an expanding machine.

5.3 Expanded joints shall not be used on Class I piping systems as defined in 46CFR56.04 for United States Coast Guard inspected and certified vessels.

5.4 Perform a minimum of three expansions to ensure the degree of expansion.

5.5 Bevel the unexpanded end of pipe/tube 30 to 40° for copper-nickel alloy and 10 to 20° for stainless steel.

5.6 Clean the pipe/tube ends to be inserted into the silver-brazed expanded pipe/tube socket and the interior of the socket itself to a bright metal before insertion.

5.7 Align pipe/tube ends concentrically as accurately as possible, and preserve this alignment during the welding process.

5.8 Provide a gap of approximately \(\frac{1}{6}\) in. (1.5 mm) (expanded welded socket joint, Fig. 1) and \(\frac{1}{4}\) in. (3 mm) (expanded silver-brazed joint, Fig. 2) between the end of the
pipe/tube and the bottom of the socket by bottoming the pipe/tube and backing off slightly before tacking.

5.9 The minimum insertion length shall be 1 in. (25 mm).

5.10 For United States Navy Application (see NAVSEA Document 0900-LP-001-7000), on the pipe/tube inserted into the expanded joint make a light scribe line a distance of 2 in. (50 mm) from the end of the unexpanded pipe/tube. This scribe line shall be visible at the time of final inspection.

5.11 The filler metal used in brazing shall be a nonferrous metal or alloy having a melting point above 1000°F (537°C) and below that of the metal being joined.

5.12 The brazing material shall have a shearing strength of at least 10 000 psi (68 950 KPa).

6. Dimensions and Tolerances

6.1 Dimensions are as indicated in Fig. 1.

6.2 The inside diameters of pipe/tube in socket joints must be aligned as accurately as practicable. Alignment must be preserved during welding.

6.3 Pipe/tube ends in socket joints shall provide a maximum radial clearance between pipe/tube outside radius and socket inside radius of the following:

6.3.1 Welded Socket Joints—0.012 in. (0.305 mm) maximum.

6.3.2 Silver-Brazed Joints—0.002 to 0.006 in. (0.050 to 0.150 mm).

6.4 Wall thickness thinning shall be less than 10 % for all sizes, and in no case shall the minimum wall thickness after expansion be less than the values for \( T_1 \) in Table 1.

7. Welding and Brazing

7.1 Welding shall be as shown on Fig. 1.

7.2 Brazing shall be as shown on Fig. 2.

7.3 Welding and brazing shall be in accordance with Section IX of the ASME Boiler Code.

8. Workmanship, Finish, and Appearance

8.1 Surface areas and pipe/tube ends shall be free of weld spatter, burrs, sharp corners, and edges hazardous to personnel.
1. Scope

1.1 This specification provides the requirements for mattresses and box springs that are for use in berths for officers, crew, and passengers in marine vessels. This shall be considered a minimum standard.

1.2 The values stated in inch-pound SI units are to be regarded as the standard (except where such units are not present, when discussing fire test methods), standard. The values given in parentheses, in SI inch-pound units, are for information only.

1.3 This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire-hazard or fire-risk assessment of the materials, products, or assemblies under actual fire conditions.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
2. Referenced Documents

2.1 ASTM Standards:

D 123 Terminology Relating to Textiles
D 1424 Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus
D 3574 Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams
D 3951 Practice for Commercial Packaging
D 5034 Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)
D 6193 Practice for Stitches and Seams

D 6413 Test Method for Flame Resistance of Textiles (Vertical Test)
E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
E 176 Terminology of Fire Standards
E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials
E 1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
F 1566 Test Methods for Evaluation of Innersprings and Box Springs
E 1590 Test Method for Fire Testing of Mattresses

2.2 ANSI Standards:

ANSI Z357.1-1981 American National Standard for Bedding Products and Components
ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes

2.3 California Bureau of Home Furnishings and Thermal Insulation Standard:


2.4 Federal Standards:

Code of Federal Regulations Title 16, Vol 2, Part 1632
Purchase Description—Mattress—Innerspring, Flame-Resistant, Shipboard—NAVSEA 05L PD 4-02 (May 2002)

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2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards, volume information, refer to the standard’s Document Summary page on the ASTM website.


4 Available from California Bureau of Home Furnishings and Thermal Insulation, 3483 Orange Grove Ave., North Highlands, CA 95660.


6 Available from NAVSEA, Naval Sea Systems Command, Dept. of Navy, 1333 Isaac Hull Ave., STOP 5149 (SEA 05P6), Washington Navy Yard, DC 20376-5149.
3. Terminology

3.1 **Definitions**—For definitions of terms used in this specification associated with textiles, see Terminology D 123. For definitions of terms used in this specification associated with fire issues, see Terminology E 176.

3.2 **Definitions of Terms Specific to This Standard**:

3.2.1 **border**, n—a material that forms the side panel that surrounds the perimeter of the mattress and defines its depth.

3.2.2 **box spring**, n—a foundation for a mattress, consisting of wire spring elements mounted on a frame, generally upholstered and covered on the top and sides with ticking, and on the bottom with a dust cover.

3.2.3 **box spring assembly**, n—an interconnection of coil springs, border wire, and top wire assembly contained within a box spring.

3.2.4 **flaming droplets**, n—drops of material exhibiting evidence of flames when falling—flaming molten or flaming liquefied droplets which fall from the test specimen during the fire test and that continues exhibiting evidence of flames for a period of at least 10 s—continue to burn.

3.2.5 **flange**, n—strip of material secured to the perimeter of an upholstery panel to secure to the innerspring core.

3.2.6 **innerspring unit**, n—an interconnection of wire spring elements other than mounting on a frame that forms a single unit that can be incorporated into a mattress.

3.2.7 **insulator pad**, n—one or more layers of a cushioning system between the upholstery and mattress core, which consist of foam or other cushioning or filling materials.

3.2.8 **mattress**, n—ticking filled with a resilient material used alone or in combination with other products intended or promoted for sleeping upon.

3.2.9 **mattress core**, n—the main support system that may be present in a mattress, such as springs, foam, or resilient filling.

3.2.10 **mattress, innerspring**, n—any mattress containing an innerspring unit.

3.2.11 **mattress, solid core**, n—any mattress containing padding, but not an innerspring unit.

3.2.12 **quilted, adj**—stitched with any thread or by fusion through the ticking and one or more layers of upholstery material.

3.2.13 **tape edge**, n—seam or border edge of a mattress.

3.2.14 **ticking**, n—the outermost layer of fabric or related material that encloses the core and upholstery materials of a mattress or mattress pad.

4. Ordering Information

4.1 Orders for items purchased under this specification shall define the following:

4.1.1 **Mattresses**—Quantity, dimensional requirements, type (solid core or innerspring), and weight per each size.

4.1.2 **Box Springs**—Quantity, dimensional requirements, and weight per each size.

4.1.3 Upholstery material selections are to be offered as choices by the manufacturer or distributor to the purchaser. The selection shall be of good quality suitable for commercial use and for use aboard U.S. Navy vessels.

4.1.4 When first article of inspection is required, it shall be spelled out in the paperwork.

5. Materials and Manufacture

5.1 **Innerspring Mattress**—The essential components of an innerspring mattress are: an innerspring core, cushioning, upholstery ticking (either quilted or with a smooth top, and potentially including a flange), and a border. Optional components include various insulating layers or pads, flanges, and tapes. All materials used shall meet the mechanical property and fire performance requirements of Table 1. All materials used shall comply with appropriate commercial bedding industry standards of manufacture and durability. Any construction of an innerspring mattress that is suitable for its intended use and that complies with the performance requirements shown herein shall be permitted to be used.

5.1.1 **Innerspring Core**—The innerspring core shall be constructed from an all-wire carbon steel. The coils shall extend the full length and width of the mattress. The coils shall be permanently secured to provide long-term structural stability. Various core designs shall be permitted. The support properties of the innerspring core, in terms of firmness rating, durability, resistance to impact, firmness retention, and surface deformation, shall be assessed by Test Methods F 1566. The coils, or the complete spring unit assembly, shall be given suitable thermal treatment to relieve residual stresses caused by coiling.

5.1.2 **Cushioning and Insulator Layers**—An insulator pad shall be placed over each sleeping surface of the innerspring core to insulate the upholstery from the core. The various cushioning layers shall be constructed of materials that meet the performance requirements of Table 1.

5.1.3 **Ticking and Cover Assembly**—The cover construction shall be suitable for the type of mattress construction used. Upholstery ticking materials shall be durable, per common bedding industry practices. The ticking for each sleeping surface shall

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Footnote:

7 Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.
be cut in one piece without fabric splices. The ticking for the mattress border shall be made of not more than two pieces of ticking, with the ends spliced and sewn together in a continuous manner leaving no gaps or voids in uniformity and finish. The border assembly shall be secured to the top and bottom sleeping surfaces of the mattress, by automatic sewing, per common bedding industry practices.

5.1.4 Border—The ticking for the mattress border shall be made of not more than two pieces of ticking, with the ends spliced and sewn together in a continuous manner leaving no gaps or voids in uniformity and finish. The border assembly shall be secured to the top and bottom sleeping surfaces of the mattress, by automatic sewing, per common bedding industry practices.

5.1.5 Tape—A tape shall be permitted to be used to conceal the seams formed between the border, if present, and an upholstery panel. The tape shall be continuously stitched along the total length of each seam, with no gaps or voids between the upholstery panel and border surfaces.

5.1.6 Seam and Stitching—The seam and stitch types shall be in accordance with Practice D 6193. All seams shall be securely stitched. Seams shall not slip or pull out.

5.1.7 Mattress—All mattress components shall meet the requirements of Table 1, as appropriate. The overall mattress shall meet the performance requirements of Table 2, as discussed in Section 6. For dimensional requirements, see 6.6.

5.1.7.1 Upholstery ticking, as well as any flange, tape, and pocketing materials used, shall exhibit a char length not exceeding 5.0 in. (127 mm), an after flame period not exceeding 2.0 s, and shall not exhibit any molten or flaming droplets, or both, when tested in accordance with Test Method D 6413. The char length and after flame requirements shall not apply to tape.

5.1.7.2 Upholstery ticking, as well as any flange, tape, and pocketing materials used, shall exhibit a char length not exceeding

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**TABLE 1 Mattress Component Requirements**

<table>
<thead>
<tr>
<th>Component</th>
<th>Characteristic</th>
<th>Requirement</th>
<th>Test Method</th>
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<tr>
<td>Upholstery Ticking (and Flange, Tape, and Pocketing Materials, if used) (Notes 1 and 2)</td>
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<td>≤ 5.0 in. (127 mm)</td>
<td>Test Method D 6413</td>
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<tr>
<td></td>
<td>After Flame</td>
<td>≤ 2.0 s</td>
<td>Test Method D 6413</td>
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<tr>
<td></td>
<td>No Flaming Droplets</td>
<td></td>
<td>Test Method D 6413</td>
</tr>
<tr>
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<td>Flammability after 15 Launderings</td>
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<td>Test Method D 6413</td>
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<td></td>
<td>Char Length</td>
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<td>After Flame</td>
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<td>Test Method D 6413</td>
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<td>No Flaming Droplets</td>
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<td>Test Method D 6413</td>
</tr>
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<td>Other Properties</td>
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<tr>
<td></td>
<td>Tear Strength (Note 3)</td>
<td>Warp: 3.5 lb min;</td>
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<td>Filling: 3.5 lb min;</td>
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<td>Filling: 1.6 kg (3.5 lb) min;</td>
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<td>Breaking Strength (Note 3)</td>
<td>Warp: 94 lb min;</td>
<td>Test Method D 5034</td>
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<td>Filling: 58 lb min;</td>
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<td>Filling: 20.3 kg (58 lb) min;</td>
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<td>After Flame</td>
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<td>Tear Strength</td>
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<td>Warp: 1.8 kg (4 lb) min;</td>
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<td></td>
<td></td>
<td>Filling: 1.8 kg (4 lb) min;</td>
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<td>Filling: 50 lb min;</td>
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<td>Breaking Strength</td>
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<td>Filling: 25.3 kg (50 lb) min;</td>
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<tr>
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<td>Char Length</td>
<td>≤ 5.0 in. (127 mm)</td>
<td>Test Method D 6413</td>
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<td>Test Method D 6413</td>
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<td></td>
<td>Other Properties</td>
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<td>Test Method E 662</td>
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<tr>
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<td>Dry Heat Aging /</td>
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<td>Compression Force Deflection</td>
<td>compression force deflection</td>
<td>Methods C and K</td>
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</table>

**NOTE 1**—Only Molten and/or Flaming Droplets requirement applies to Tape.

**NOTE 2**—Only Initial Flammability requirements apply to Pocketing Material.

**NOTE 3**—Tear Strength and Breaking Strength apply only to Upholstery Ticking.

**NOTE 4**—When materials are not identical on both sides, each side shall be tested as a different specimen.
5.0 in. (127 mm), 127 mm (5.0 in.), an after flame period not exceeding 2.0 s, and shall not exhibit any molten or flaming droplets, or both, when tested in accordance with Test Method D 6413, after having been subjected to 15 launderings. The char length and after flame requirements shall not apply to tape.

5.1.7.3 Border ticking materials shall exhibit a char length not exceeding 1.5 in. (38 mm), 38 mm (1.5 in.), an after flame period not exceeding 2.0 s, and shall not exhibit any molten or flaming droplets, or both, when tested in accordance with Test Method D 6413. Border ticking materials shall also exhibit a maximum specific optical density ($D_{\text{MAX}}$) not exceeding 50, and shall not exhibit any molten or flaming droplets, or both, when tested in accordance with Test Method E 662.

5.1.7.4 Cushioning and insulator layer materials shall exhibit a char length not exceeding 5.0 in. (127 mm), 127 mm (5.0 in.), an after flame period not exceeding 2.0 s, and shall not exhibit any molten or flaming droplets, or both, when tested in accordance with Test Method D 6413. Cushioning and insulator layer materials shall also exhibit a radiant panel index (J) not exceeding 10 when tested in accordance with Test Method E 162. Cushioning and insulator layer materials shall also exhibit a maximum specific optical density ($D_{\text{MAX}}$) not exceeding 200, and shall not exhibit any molten or flaming droplets, or both, when tested in accordance with Test Method E 662. When materials are not identical on both sides, each side shall be tested as a different specimen, with Test Method E 162 and with Test Method E 662. An optional additional fire test, applicable if the mattress is intended for use aboard U.S. Navy vessels, is shown in Annex A2.

5.1.7.5 Physical Properties:

1. Upholstery ticking materials shall exhibit a tear strength of no less than 1.6 kg (3.5 lb) in either the warp or the filling direction when tested in accordance with Test Method D 1424. Upholstery ticking materials shall also exhibit a breaking strength of no less than 42.6 kg (94 lb) in the warp direction and of no less than 26.3 kg (58 lb) in the filling direction when tested in accordance with Test Method D 5034.

2. Border ticking materials shall exhibit a tear strength of no less than 1.8 kg (4 lb) in either the warp or the filling direction when tested in accordance with Test Method D 1424. Border ticking materials shall exhibit a breaking strength of no less than 42.6 kg (94 lb) in the warp direction and of no less than 22.7 kg (50 lb) in the filling direction when tested in accordance with Test Method D 5034.

3. Cushioning and insulator layer materials shall exhibit a dry heat aging/compression force deflection of no more than 20 % change in compression force deflection when tested in accordance with Sections C and K of Test Method D 3574.

5.1.8 Label—The label shall state that the mattress meets one of the following sets of fire test requirements: (1) this specification (per Table 1 and Table 2), (2) California Technical Bulletin 129, or (3), Purchase Description—Mattress—Innerspring, Flame-Resistant, Shipboard—NAVSEA 05L PD 4-02 (May 2002).

5.2 Solid Core Mattress—The required components of a solid core mattress are cushioning and upholstery ticking.

5.2.1 All materials used shall meet the mechanical property and fire performance requirements of Table 1, as indicated in 5.1, for innerspring mattresses, as applicable. All materials used shall comply with appropriate commercial bedding industry standards of manufacture and durability.

5.2.2 Mattress—All mattress components shall meet the requirements of Table 1, as appropriate. The overall mattress shall meet the performance requirements of Table 2.

5.2.3 Label—The label shall state that the mattress meets one of the following sets of fire test requirements: (1) this specification (per Table 1 and Table 2), (2) California Technical Bulletin 129, or (3), Purchase Description—Mattress—Innerspring.
5.3 Box Spring—The tolerances of the overall length, width and thickness dimensions of the box spring shall be consistent with the mattress dimensions. Fig. 1 shows an example of a typical design of box spring. The top wire assembly shall be attached securely to the border wire.

5.3.1 The individual coils shall be securely attached to the top wire assembly. The coils, or the complete spring assembly, shall be given thermal treatment to relieve residual stresses caused by coiling. The wood frame assembly shall be suitable for commercial use or for use aboard U.S. Navy vessels. All four corners shall be suitably fastened at each point of attachment, in accordance with standard commercial bedding practices. All bottom edges shall be eased (sharp corners blunted by sanding). The wood base frame shall be constructed of industry standard box spring frame lumber, typically Eastern Canadian spruce or Southern yellow pine. The spring assembly shall be attached to the wood base frame.

5.3.2 Cushioning, Insulation Layers, Ticking and Construction —The requirements for materials and manufacture of all other components shall be as those for innerspring mattresses, in 5.1, as applicable. The insulation layer shall be attached to the top surface to prevent slippage. Each corner shall be filled with cushioning material, to provide proper tailoring. The box spring border ticking shall be of the same material as that of the mattress. The top panel shall be of a material that retards slipping. The cover assembly shall be placed over the top of the steel and wood assembly and properly attached, in accordance with standard commercial bedding practices.

5.3.3 The box spring shall display trade labels regarding material content and manufacturer as required by law.

5.3.4 Label—The label shall state that the box spring meets one of the following sets of fire test requirements: (1) this specification (per Table 1 and Table 2), (2) California Technical Bulletin 129, or (3), Purchase Description—Mattress—Innerspring, Flame-Resistant, Shipboard—NAVSEA 05L PD 4-02 (May 2002).

5.4 Mattress/Box Spring:

5.4.1 Packaging shall protect the products from physical damage and be acceptable to a common carrier.

5.4.2 Each item shall be clearly marked in accordance with the purchase order requirements.

6. Performance Requirements for the Complete Mattress

6.1 The complete mattress shall meet the performance requirements shown in Table 2.

6.2 Fire Performance Requirements — At a minimum, the mattress shall comply with the requirements of 6.2.1-6.2.4 (consistent with those contained in NFPA 301).

6.2.1 The mattress ticking shall pass the requirements for Class A performance in accordance with 16 CFR 1632.

6.2.2 The mattress shall exhibit a maximum rate of heat release not exceeding 100 kW when tested in accordance with Test Method E 1590.

6.2.3 The mattress shall exhibit a total heat released in the first 10 min of test not exceeding 25 MJ when tested in accordance with Test Method E 1590.
6.2.4 The mattress shall exhibit a mass loss in the first 10 min of test not exceeding 1.4 kg (3 lb) when tested in accordance with Test Method E 1590.

6.3 **Optional Fire Performance Requirements**—As an option, the mattress shall be permitted to exhibit fire performance in accordance with the fire test method described in Annex A1. This will involve, at a minimum, that the mattress comply with the requirements of 6.3.1-6.3.3. If a mattress is intended for use aboard U.S. Navy vessels, it shall be required to comply with the criteria shown in 6.3.1-6.3.3, when tested in accordance with the fire test method described in Annex A1.

6.3.1 The mattress shall exhibit a maximum rate of heat release, during the test, not exceeding 150 kW.

6.3.2 The mattress shall exhibit a maximum average specific extinction area, during the test, not exceeding 300 m²/kg.

6.3.3 The mattress shall not exhibit flaming droplets during the test.

6.4 **Physical Characteristics:**

6.4.1 The mattress shall exhibit a firmness rating of 330 N (75 lbf) ± 10 %, and shall not exhibit any signs of wear, tear, damage, or degradation, when tested for 100 000 cycles in accordance with Section 7 of Test Method F 1566. The test report shall include the initial firmness rating, the firmness rating after 25 000, 50 000, and 75 000 cycles, as well as the final firmness rating after 100 000 cycles. The test report shall also include any signs of wear, tear, damage, or degradation on any part of the mattress when inspected after each set of 25 000 cycles.

6.4.2 The mattress shall exhibit a permanent deformation not exceeding 20 % of depth, when tested in accordance with the Rollator Test section of Test Method F 1566.

6.4.3 The mattress shall exhibit an accumulated dimple not to exceed 1.75 in. (44.5 mm), 44.5 mm (1.75 in.), when tested in accordance with the Cornell Test section of Test Method F 1566.

6.4.4 The mattress shall exhibit a support firmness change not exceeding (+40 %) or (-15 %), when tested in accordance with the Cornell Test section of Test Method F 1566.

6.5 **Visual Inspection**—Visual inspection shall be conducted to check for any defects in the finished mattress, as shown in Table 3. The finished mattresses shall be clean and free from defects and other conditions affecting form, fit, function, and appearance. The lot size shall be expressed in units of mattresses. The sample unit shall be one mattress. The inspection shall be performed in accordance with ANSI/ASQC Z1.4.

6.6 Dimensional requirements for mattresses are contained in ANSI A.357.1-1981. Dimensional requirements for innerspring mattresses intended for use aboard U.S. Navy vessels are contained in Purchase Description—Mattress—Innerspring, Flame-Resistant, Shipboard—NAVSEA 05L PD 4-02 (May 2002).

**NOTE 1**—Dimensional requirements in NAVSEA 05L PD 4-02 are contained in inch-pound units.

7. **Workmanship, Finish and Appearance**

7.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice so as to prevent any damage to the item.

<table>
<thead>
<tr>
<th>TABLE 3 Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material</strong></td>
</tr>
<tr>
<td><strong>Construction</strong></td>
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<tr>
<td><strong>Construction</strong></td>
</tr>
<tr>
<td><strong>Labels</strong></td>
</tr>
<tr>
<td><strong>Cleanliness</strong></td>
</tr>
<tr>
<td><strong>Cleanliness</strong></td>
</tr>
</tbody>
</table>
produce each item suitable for its intended use.

7.2 Where first article inspection is required, it shall be spelled out in the purchase order.

8. Inspection and Certification

8.1 The manufacturer or distributor shall issue a certificate of conformance for each shipment of mattresses and of box springs to this specification. In addition, the manufacturer or distributor shall have available (upon request) independent test data to depict compliance with the stated fire test criteria, either for Test Method E 1590 or for the test method described in Annex A1 of this specification. The independent test data shall always reflect a test date not to exceed a time period of three years from the date of product shipment.

9. Keywords

9.1 berths; box springs; fire; fire test; heat release; innerspring mattress; marine; marine berth mattress; naval vessel; solid core mattress

ANNEXES

(Mandatory Information)

A1. FIRE TEST METHOD FOR MATTRESSES FOR USE IN HIGH RISK MARINE VESSEL OCCUPANCIES

A1.1 This fire test method is a modification of the one in Test Method E 1590, as developed by the U.S. Navy for determining the acceptability of mattresses for use aboard marine vessels. It assesses the burning behavior of mattresses by determining heat release, smoke release, mass loss, and combustion product release when a mattress is subjected to a specified flaming ignition source under well-ventilated conditions.

A1.2 Apparatus and Procedure:

A1.2.1 The apparatus shall be as described in Section 6 of Test Method E 1590, except as indicated in A1.3.

A1.2.2 The test specimen shall be as described in Section 7 of Test Method E 1590, except as indicated in A1.3.

A1.2.3 The calibration of instrumentation shall be as described in Section 8 of Test Method E 1590.

A1.2.4 The test specimen conditioning shall be as described in Section 9 of Test Method E 1590.

A1.2.5 The test procedure shall be as described in Section 10 of Test Method E 1590, except as indicated in A1.3.

A1.2.6 The calculations shall be as described in Section 11 of Test Method E 1590, except as indicated in A1.3.

A1.2.7 The test report shall be as described in Section 12 of Test Method E 1590, except for the additional information required in A1.45.

A1.3 Test Method Modifications for This Standard:

A1.3.1 The test specimen shall be a full sized mattress, mounted on an open flame bunk or support system that will allow direct flame impingement to the bottom surface and sides of the mattress by the ignition source.

A1.3.2 Replace the “T” burner described in 6.2 of Test Method E 1590 with a burner having a nominal 0.3 by 0.3 m (1 by 1 ft) top surface. The burner shall have a minimum 102 mm (4 in.) layer of Ottawa silica sand, to provide the horizontal surface through which the gas is supplied. The sand layer shall be flush with the top of the burner. The burner shall be positioned such that the top edge of the burner is 380 ± 13 mm (15 ± 0.5 in.) below the bottom edge of the test specimen and centered with respect to the long side of the test specimen, with one-half of the width of the burner under the mattress.

A1.3.3 Support the mattress on a metal bed frame, constructed of heavy angle section iron, with all joints welded. The bed frame shall be nominally 1.94 by 0.76 m (76 by 30 in.) and shall contain a wire grid, constructed of nominally 2 mm (0.08 in., 12.5 gage) welded steel wire mesh, with nominally 51 by 102 mm (2 by 4 in.) openings, secured to the perimeter of the bed frame with steel tie wires.

A1.3.4 The test specimen shall be exposed to a fire producing a total heat output of 50 ± 3 kW (47.6 ± 2.86 Btu/s) for the first 5 min of the test followed by an increase to 100 ± 5 kW (95.2 ± 4.76 Btu/s) for an additional 10 min. The total fire exposure shall be 15 min.

A1.3.45 Report the average specific extinction area from the test (m²/kg), which is assessed as the total smoke released (m²) divided by the total mass loss (kg).

A1.4 Critical Test Results—The following three test results shall be presented in a summary table: (a) the maximum rate of heat release obtained during the test minus the burner heat input at the time the maximum heat release rate occurs, (b) the average specific extinction area from the test, and (c) a visual report as to whether or not burning droplets were formed and dropped to the floor or the top of the mattress platform. These critical test results are used for the pass-fail criteria described in 6.3, if the mattress is required to pass this test.
A2. OPTIONAL COMPONENT FIRE TEST METHOD FOR CUSHIONING MATERIALS FOR MATTRESSES FOR USE IN HIGH RISK MARINE VESSEL OCCUPANCIES

A2.1 If required, use Test Method E 1354 for assessing the heat release rate of cushioning materials to be included in mattresses for use aboard U.S. Navy vessels, under the conditions of A2.2 and with the pass/fail criteria of A2.3.

A2.2 The cushioning material shall be tested at an incident heat flux of 50 kW/m², in the horizontal orientation and at a thickness of 50 mm (approximately 2 in.). Testing shall be conducted in triplicate.

A2.3 Pass/Fail Criteria:

A2.3.1 The maximum rate of heat release of the cushioning material (average of the three replicate tests) shall not exceed 120 kW/m².

A2.3.2 The average rate of heat release of the cushioning material during the three minutes following ignition (average of the three replicate tests) shall not exceed 50 kW/m².

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1. Scope

1.1 This specification provides the material requirements, construction, installation, and testing requirements for open-weather deck, storm-and-guard, fiberglass square railing systems. Components are to be manufactured by the pultrusion process.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information purposes only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 9, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D 570 Test Method for Water Absorption of Plastics
D 638 Test Method for Tensile Properties of Plastics
D 695 Test Method for Compressive Properties of Rigid Plastics
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D 3846 Test Method for In-Plane Shear Strength of Reinforced Plastics
D 3917 Specification for Dimensional Tolerance of Thermosetting Glass-Reinforced Plastic Pultruded Shapes
E 84 Test Method for Surface Burning Characteristics of Building Materials

3. Terminology Definition

3.1 pultrusion—process of pulling fiberglass rovings (strands), mats, and other forms of reinforcements such as woven fiberglass through baths of thermosetting liquid resin, and then through a heated forming die (made of steel) to form a completed composite fiberglass structural shape.

3.2 Discussion—The heated die causes a chemical reaction to be initiated in the resin. The liquid resin molecules will cross-link and develop into a hardened plastic that is reinforced with the fiberglass.

4. Classification

4.1 Handrails and stanchions shall be fiberglass pultruded square tube available in the following two types:

4.1.1 Type 1F—Three-course railing systems, for use along the exposed peripheries of freeboards, weather decks, and superstructure decks.

4.1.2 Type 2F—Two-course railing systems, for use on bridges, platforms, walkways, and elsewhere as needed.

5. Ordering Information

5.1 Orders for materials under this specification shall include the following information:

5.1.1 Quantity (lineal feet (metres) of railing system).

5.1.2 Name of material (fiberglass pultruded square railing system).

5.1.3 Type (see 4.1).

5.1.4 Fiberglass coaming, if specified (lineal feet (metres)).

5.1.5 Attachment method for stanchions (see 6.2.6).

5.1.6 ASTM designation and year of issue.

6. Materials and Manufacture

6.1 Materials:

6.1.1 The fiberglass (GRP) pultruded square tube shall be $2 \times 2 \times \frac{1}{4}$ in. ($50 \times 50 \times 6.4$ mm) with the outside corner radius $\frac{3}{32}$ in. (4 mm). A synthetic surface veil shall be the outermost layer of reinforcement covering the entire exterior surface. The resin used throughout the part shall be either a flame retardant isophthalic polyester or a flame retardant vinyl ester resin containing an ultra-violet radiation (UV) inhibitor. The fiberglass pultruded square tube shall achieve a flame...
spread index of 25 or less rating in accordance with Test Method E 84. In addition, the fiberglass pultruded square tube shall achieve a smoke developed index of 450 or less. The exterior of the pultruded square tubing shall have a 1 mil (0.025 mm) minimum polyurethane protective coating for added ultraviolet protection. The fiberglass pultruded square tubing shall meet the properties specified in Table 1 and dimensional tolerances shall be in accordance with Specification D 3917.

6.1.2 Fiberglass sheet or solid fiberglass bar shall be used to fabricate the internal connectors for the square tube. The internal connectors will be 1 1/2 × 1 1/2 in. (38.1 × 38.1 mm) with length and angularity variable to meet the requirements of each connection. Angular connections shall be fabricated from fiberglass sheet bonded together using a bisphenol A/epichlorohydrin epoxy resin with an amine curing agent to give a minimum thickness of 1 1/2 in. (38.1 mm). The angular connections will be fabricated to the proper dimension from the fiberglass sheets that have been bonded together. Fiberglass sheet used for angular connections shall meet the properties specified in Table 1. Fiberglass sheet used for the straight connections shall meet the properties specified in Table 1. Fiberglass solid bar, 1 1/2 × 1 1/2 in. (38.1 × 38.1 mm), shall be used for the straight connections and shall meet the properties specified in Table 1.

6.1.3 Rivets shall be nickel copper or nonmetallic.

6.1.4 Bolts shall be 1/2 in. (12.7 mm) diameter, 316 stainless steel.

6.1.5 Adhesive used to bond internal connectors to fiberglass pultruded square tube shall be a bisphenol A/epichlorohydrin epoxy resin with an amine curing agent.

6.2 Manufacture:

6.2.1 There shall be a minimum clearance of 4 in. (101 mm) between rail or stanchion centerline and other structure except where a direct tie-in is desired.

6.2.2 Stanchions and standoffs are to be spaced on 5 ft (1.52 m) maximum centers.

6.2.3 All top rails are to be located 42 in. (1.067 m) above the deck (deck to top of square tube).

6.2.4 Railing system height for ladders shall be measured vertically from the nosing line.

6.2.5 Coaming constructed of fiberglass pultruded material shall meet the properties specified in Table 1. fiberglass coaming shall be 4 in. (101 mm) in vertical height from its top edge to the level of the deck. Fiberglass coaming shall be a corrugated or channel design with a minimum of 1/2 in. (12 mm) deep section or minimum 1/2 in. channel leg to develop added strength. It shall be securely fastened to the stanchion using nickel-copper rivets and with not more than 1/4 in. (6.4 mm) clearance above floor level. The thickness shall be at least 3/16 in. (4.75 mm) with the overall depth not more than 1 in. (25.4 mm). See Fig. 1 for example.

6.2.6 Fiberglass square tube rail stanchions shall be attached to the deck or structural supports as follows:

6.2.6.1 Attached to steel coaming (Fig. 2).

6.2.6.2 Inserted in pedestal/stanchion mount (Fig. 3).

6.2.6.3 Attached to structural members (Fig. 4).

6.2.6.4 Attached to steel angle (Fig. 5).

7. Dimensions

7.1 Dimensions for Type 1F—Three-course rails shall be in accordance with Fig. 6.

---

**TABLE 1 Fiberglass Pultruded Material Properties**

<table>
<thead>
<tr>
<th>Test Method</th>
<th>psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate tensile strength in longitudinal direction</td>
<td>D 638 30 000 (207), min</td>
</tr>
<tr>
<td>Ultimate compressive strength in longitudinal direction</td>
<td>D 695 30 000 (207), min</td>
</tr>
<tr>
<td>Ultimate flexural strength in longitudinal direction</td>
<td>D 790 30 000 (207), min</td>
</tr>
<tr>
<td>Ultimate shear strength in longitudinal direction</td>
<td>D 3846 5500 (38), min</td>
</tr>
<tr>
<td>Ultimate tensile strength in transverse direction</td>
<td>D 638 7000 (48), min</td>
</tr>
<tr>
<td>Ultimate compressive strength in transverse direction</td>
<td>D 695 15 000 (103), min</td>
</tr>
<tr>
<td>Ultimate flexural strength in transverse direction</td>
<td>D 790 10 000 (69), min</td>
</tr>
<tr>
<td>Ultimate shear strength in transverse direction</td>
<td>D 3846 5500 (38), min</td>
</tr>
<tr>
<td>Density (lb/in.³ (kg/mm³))</td>
<td>D 792 0.065 (0.00180), min</td>
</tr>
<tr>
<td>Water absorption (24-h immersion)</td>
<td>D 570 0.60 max, % by weight</td>
</tr>
</tbody>
</table>

**Specifications for Pultruded Fiberglass Sheet:**

<table>
<thead>
<tr>
<th>Test Method</th>
<th>psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate tensile strength in longitudinal direction</td>
<td>D 638 20 000 (138), min</td>
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<tr>
<td>Ultimate compressive strength in longitudinal direction</td>
<td>D 695 25 000 (172), min</td>
</tr>
<tr>
<td>Ultimate flexural strength in longitudinal direction</td>
<td>D 790 30 000 (207), min</td>
</tr>
<tr>
<td>Ultimate shear strength in longitudinal direction</td>
<td>D 3846 5500 (38), min</td>
</tr>
<tr>
<td>Ultimate tensile strength in transverse direction</td>
<td>D 638 10 000 (69), min</td>
</tr>
<tr>
<td>Ultimate compressive strength in transverse direction</td>
<td>D 695 15 000 (103), min</td>
</tr>
<tr>
<td>Ultimate flexural strength in transverse direction</td>
<td>D 790 13 000 (90), min</td>
</tr>
<tr>
<td>Ultimate shear strength in transverse direction</td>
<td>D 3846 5500 (38), min</td>
</tr>
<tr>
<td>Density (lb/in.³ (kg/mm³))</td>
<td>D 792 0.064 (0.00177), min</td>
</tr>
<tr>
<td>Water absorption (24-h immersion)</td>
<td>D 570 0.50 max, % by weight</td>
</tr>
</tbody>
</table>

**Specifications for Pultruded 1 1/2 × 1 1/2 in. (38.1 × 38.1 mm) Solid Fiberglass Bar:**

<table>
<thead>
<tr>
<th>Test Method</th>
<th>psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate tensile strength in longitudinal direction</td>
<td>D 638 100 000 (689), min</td>
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<tr>
<td>Ultimate compressive strength in longitudinal direction</td>
<td>D 695 60 000 (414), min</td>
</tr>
<tr>
<td>Ultimate flexural strength in longitudinal direction</td>
<td>D 790 100 000 (689), min</td>
</tr>
<tr>
<td>Density (lb/in.³ (kg/mm³))</td>
<td>D 792 0.074 (0.00205), min</td>
</tr>
<tr>
<td>Water absorption (24-h immersion)</td>
<td>D 570 0.25 max, % by weight</td>
</tr>
</tbody>
</table>
8. Workmanship, Finish, and Appearance

8.1 All cut edges and holes shall be sealed with a compatible resin system containing a UV inhibitor.

8.2 All connections shall be made using a one piece solid internal connector (in accordance with 6.1.2) bonded to the interior of the square tube using an epoxy adhesive and riveted. The following types of connections are defined:

8.2.1 Corner connection (Fig. 7).
8.2.2 Splice (Fig. 8).
8.2.3 Midrail to stanchion (Fig. 9).
8.2.4 Top rail to stanchion (Fig. 10).
8.2.5 Stair railing system to stanchion (Fig. 11).
8.2.6 Stair rail to rail (Fig. 12).

8.3 All bolted connections shall have a one-piece solid internal connector (in accordance with 6.1.2) bonded to the interior of the square tube through which connector holes will be drilled. A minimum 1 in. (26 mm) length of the solid internal connector will be on each side of the drilled hole.

8.4 Additional solid internal connector pieces can be bonded with epoxy adhesive to the interior of the square tube as desired.

9. Test Methods

9.1 Test at least one end stanchion and one other stanchion of each platform or deck by application of a load horizontally in accordance with the methods in “Strength and Stiffness of Metal Railing Systems and Rails for Buildings.”

10. Keywords

10.1 fiberglass rails; marine; open-weather deck; pultruded; railing system; ship; square rails; storm-and-guard

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7.2 Dimensions for Type 2F—Two-course rails shall be in accordance with Fig. 1.
**NOTE 1**—All joints to be epoxied and bolted or riveted.

**FIG. 3 Pedestal/Stanchion Mount**

**Welded to Steel Deck**

(Alternate—FRP Bolted to STL &)

(Steel Welded to Floor—See Alt Detail FIG 3)

Note 1—All joints to be epoxied and bolted or riveted.

**FIG. 4 Railing System Stanchions—Structural Members**
L6 x 3 x 1/4 x 0.7 (156 mm x 76 mm x 6.4 mm x 177 mm) STEEL ANGLE, WELDED OR STUD WELDED TO DECK

FIG. 5 Railing Systems Stanchions Anchored to Steel Deck

FIG. 6 Three-Course Rail
FIG. 7 Corner Connection

BUILT-UP PULTRUDED FIBERGLASS SHEET (TYP @ CORNERS)

3 1/2" (89 mm)

FIG. 8 Splice

1 1/2 (38 mm) SQ SOLID BAR (FIBERGLASS)
TYP @ STRAIGHT CONNECTION & PLUGS (EXPLODED INTERNALLY)

4 1/2 (114 mm)

2 1/4 (57 mm)

FIG. 1092 – 04
FIG. 9 Midrail to Stanchion

FIG. 10 Top Rail to Stanchion

MONEL (NICKEL COPPER) RIVETS & EPOXY (TYP)
FIG. 11 Stair to Stanchion
FIG. 12 Stair Rail to Rail
Standard Specification for Mortar, Refractory (High-Temperature, Air-Setting)\textsuperscript{1}

This standard is issued under the fixed designation F 1097; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers dry air-setting refractory mortar for use in laying and bonding refractory brick in ship boiler furnaces and wet air-setting refractory mortar for use in laying refractory brick in stationary boiler furnaces, bright annealing furnaces, controlled atmosphere furnaces, and furnaces heated by electric elements.

1.2 The values stated in inch-pound units are to be regarded as standard. The SI units in parentheses are for information purposes only and may be approximate.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
C 24 Test Method for Pyrometric Cone Equivalent (PCE) of Fireclay and High Alumina Refractory Materials\textsuperscript{2}
C 27 Classification of Fire Clay and High-Alumina Refractory Brick\textsuperscript{2}
C 92 Test Methods for Sieve Analysis and Water Content of Refractory Materials\textsuperscript{2}
C 133 Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories\textsuperscript{2}
C 198 Test Method for Cold Bonding Strength of Refractory Mortar\textsuperscript{2}
C 199 Test Method for Pier Test for Refractory Mortars\textsuperscript{2}
2.2 Federal Specifications\textsuperscript{3}—The following documents shall apply only when one or more of the requirements of S1 are specified in the contract or purchase order (see 4.1.3):

PPP-B-704 Pails: Shipping, Steel (1 through 12 gallon)
PPP-B-35 Bags: Textile, Shipping, Burlap, Cotton and Waterproof Laminated
PPP-B-702 Sacks, Shipping, Paper

2.3 Military Standards\textsuperscript{3}—The following documents shall apply only when one or more of the requirements of S1 are specified in the contract or purchase order (see 4.1.3):

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129 Marking for Shipment and Storage

3. Classification

3.1 The refractory mortar shall be of the following types:
3.1.1 Type 1—Dry.
3.1.2 Type 2—Wet.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information, as necessary to adequately describe the material:
4.1.1 ASTM designation and year of issue,
4.1.2 Type required (see 3.1), and
4.1.3 Optional requirements, if any (see S1).

5. Material

5.1 The mortar shall be composed of finely ground heat-resistant clays, minerals, or a mixture of clays and minerals in either a dry or wet condition.

5.1.1 Type 1, Dry—Mortar shall be furnished dry and shall be ready for use as soon as mixed with water. Mortar, after being mixed with water and then dried, shall be capable of being remixed with water.

5.1.2 Type 2, Wet—Mortar shall be furnished ready for use at a trowelling consistency and shall be easily mixed with water to a dipping consistency.

6. Performance Requirements

6.1 Resistance to Heat Soaking—Mortar shall not soften nor show any evidence of fusion, and the shrinkage shall not be greater than hairline cracks when tested as specified in 11.2.

6.2 Bonding Strength—The average modulus of rupture at the brick joint when tested as specified in 11.3 shall be not less than shown in Table 1.

6.3 Pyrometric Cone Equivalent (PCE)—The PCE shall be not less than cone 32 (see 11.4).

\textsuperscript{1} This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.


\textsuperscript{3} Standardization Documents Order Desk, Building 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, ATTN: NPODS.
7. Requirements

7.1 Fineness—Mortar shall be ground to such fineness that not more than 5% shall be retained on a No. 40 ASTM sieve, and not more than 0.5% shall be held on a No. 30 ASTM sieve (see 11.1).

7.2 Shelf Life, Type 1—Mortar shall show no deterioration after 1 year’s storage.

7.3 Shelf Life, Type 2—At any time within one year of shipment from the supplier, the mortar in a previously unopened container shall not have stiffened to such an extent as to interfere with its easy removal and mixing.

7.4 Consistency—Mortar, when tempered with water, shall be of such consistency that it will be suitable for spreading easily with a trowel or for dipping and for laying refractory brick and bonding them together upon drying and upon subsequent heating at furnace temperatures. Mortar shall retain this degree of workability for 2 h.

7.4.1 The mixed mortar shall have sufficient water retention to permit a 1/16-in. (2-mm) joint to be made with a trowelling consistency, but not allow the newly laid brick to float out of position.

8. Workmanship

8.1 Workmanship shall be first class in every respect. There shall be no foreign material or caked aggregate lumps in the mortar. Wet mortar shall be easily removed from the container and shall mix easily to a uniform trowelling consistency.

9. Sampling

9.1 An inspection lot for tests and inspections shall consist of all material manufactured at essentially the same time and of the same type offered for delivery at one time.

10. Specimen Preparation

10.1 The entire mortar sample for testing shall be thoroughly mixed to ensure uniformity before any portion is taken for tests. The selected portion of Type 1 (dry) mortar shall be mixed with water to a trowelling consistency for the tests of 11.2 and 11.3.

10.2 For the test specified in 11.3, brick-mortar joints shall be prepared in accordance with Test Method C 198, except that refractory bricks, conforming to Classification C 27, super-duty, shall be used and shall be cut in half. The two halves of each brick shall be placed in a device suitable for bringing, with a straight motion, the molded ends together with the faces parallel at all times to form a bond.

10.2.1 A small quantity of mortar shall be spread by a trowel on the upper face forming the bond to ensure intimate contact. Sufficient mortar to give a 1/8-in. (3-mm) thick layer shall be spread evenly on the lower bond forming face and the upper half shall be lowered until it is 1/16 in. (2 mm) from the lower half. The excess mortar shall be cut from the joint, flush with the sides of the brick. The unit thus formed shall be removed at once from the bond-forming machine. The bond specimens shall be allowed to air-dry for 24 h.

**TABLE 1** Bonding Strength of Mortar

<table>
<thead>
<tr>
<th>Temperatures, °F (°C)</th>
<th>Average Modulus of Rupture, psi (kPa), min</th>
</tr>
</thead>
<tbody>
<tr>
<td>230 (110)</td>
<td>200 (1400)</td>
</tr>
<tr>
<td>1000 (538)</td>
<td>100 (700)</td>
</tr>
<tr>
<td>2000 (1093)</td>
<td>100 (700)</td>
</tr>
</tbody>
</table>

9.2 For the tests specified in 11.1 through 11.4, the sample unit shall be 15 lbs (7 kg) of mortar. No fewer than three sample units shall be randomly selected throughout the lot. No more than one sample shall be drawn from any one container.

9.2.1 The test sample shall be a 45-lbs (20-kg) composite of the randomly selected sample units. Two or more determinations as applicable (see Table 2) shall be performed on the composite. There shall be no evidence of failure to meet the specified unit or average requirements.

9.3 The PCE shall be determined on two cones of different samples from each lot. If both cones fail, this shall be cause for rejection without retest. If either cone fails, three additional cones shall be made, each from a different sample. If any one of the three retest cones fail, this shall be cause for rejection.

**10. Specimen Preparation**

10.1 The entire mortar sample for testing shall be thoroughly mixed to ensure uniformity before any portion is taken for tests. The selected portion of Type 1 (dry) mortar shall be mixed with water to a trowelling consistency for the tests of 11.2 and 11.3.

10.2 For the test specified in 11.3, brick-mortar joints shall be prepared in accordance with Test Method C 198, except that refractory bricks, conforming to Classification C 27, super-duty, shall be used and shall be cut in half. The two halves of each brick shall be placed in a device suitable for bringing, with a straight motion, the molded ends together with the faces parallel at all times to form a bond.

10.2.1 A small quantity of mortar shall be spread by a trowel on the upper face forming the bond to ensure intimate contact. Sufficient mortar to give a 1/8-in. (3-mm) thick layer shall be spread evenly on the lower bond forming face and the upper half shall be lowered until it is 1/16 in. (2 mm) from the lower half. The excess mortar shall be cut from the joint, flush with the sides of the brick. The unit thus formed shall be removed at once from the bond-forming machine. The bond specimens shall be allowed to air-dry for 24 h.

**TABLE 2** Testing Requirements

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification Reference</th>
<th>Number of Determinations per Composite</th>
<th>Results Reported as</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pass or Fail&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Type 1 and Type 2, as applicable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fineess</td>
<td>Retained on No. 40 ASTM sieve</td>
<td>7.1</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>Retained on No. 30 ASTM sieve</td>
<td>7.1</td>
<td>11.1</td>
</tr>
<tr>
<td>Resistance to heat soaking</td>
<td></td>
<td>6.1</td>
<td>11.2</td>
</tr>
<tr>
<td>Bonding strength</td>
<td></td>
<td>6.1</td>
<td>11.2</td>
</tr>
<tr>
<td>After heating at</td>
<td></td>
<td>6.2</td>
<td>11.3</td>
</tr>
<tr>
<td>230°F (110°C)</td>
<td></td>
<td>11.3</td>
<td>avg of 5</td>
</tr>
<tr>
<td>1000°F (538°C)</td>
<td></td>
<td>11.3</td>
<td>avg of 5</td>
</tr>
<tr>
<td>2000°F (1093°C)</td>
<td></td>
<td>11.3</td>
<td>avg of 5</td>
</tr>
<tr>
<td>Pyrometric cone:&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td>6.3</td>
<td>11.4</td>
</tr>
</tbody>
</table>

<sup>a</sup>If failure is indicated, report description of failure or numerical point of failure as applicable.

<sup>b</sup>Test report shall include all values on which results are based.

<sup>c</sup>See 9.3.
11. Test Methods

11.1 Fineness—The fineness test shall be made in accordance with Test Methods C 92.

11.2 Heat Soak:

11.2.1 A pier of refractory brick, conforming to Classification C 27, super-duty, laid up with the test mortar shall be prepared and heated at 2910°F (1588°C) for 5 h in accordance with Test Method C 199.

11.2.2 The cooled pier shall be examined for evidence of shrinkage, softening, or fusion of the mortar. One or more mortar joints shall be broken and the freshly broken mortar surface shall be viewed from various angles. Any shininess or light flash at the mortar surface shall be considered an indication of excessive fusion.

11.3 Bonding Strength:

11.3.1 Five bond specimens (see 10.2) shall be placed in an oven operating at 230°F (110°C) for 24 h; five bond specimens shall be held at each of the other test temperatures (1000°F, 2000°F (538°C, 1093°C) for 5 h and then allowed to cool in the closed furnace for 12 to 18 h. The time required to reach test temperatures shall be 3 h. The bond shall not be broken until the specimens have reached approximately room temperature.

11.3.2 The modulus of rupture of the test specimens shall be determined in accordance with Test Methods C 133, except that the load shall be applied at the rate of 1000 lb/min (450 kg/min).

11.3.2.1 In conducting this test, bring the upper bearing edge to bear on the joint itself.

11.4 Pyrometric Cone Equivalent—The PCE shall be determined in accordance with Test Method C 24.

12. Inspection

12.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may use his own facilities or any commercial laboratory acceptable to the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

13. Packaging

13.1 Packing of the mortar shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the supply source to the first receiving activity for immediate use and may conform to the supplier’s commercial practice.

14. Keywords

14.1 bonding strength; mortar; refractory mortar

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the contract or purchase order (see 4.1.3.).

S1. Special Government Requirements

S1.1 Quality Conformance Inspection:

S1.1.1 Sampling for quality conformance inspection shall be performed in accordance with the provisions set forth in MIL-STD-105, except where otherwise indicated.

S1.1.2 Examination of the end item shall be made in accordance with the classification of defects, inspection levels, and quality levels specified in S1.1.2.1 through S1.1.2.3. The lot size, for the purpose of determining the sample size in accordance with MIL-STD-105, shall be expressed in units of filled containers for the examinations in S1.1.2.1 and S1.1.2.2.

S1.1.2.1 Examination of the end item container for defects in appearance, workmanship, closures, and marking (see Table S1.1). The sample unit for this examination shall be one filled container.

S1.1.2.2 Examination of end item container for defects in net contents. The sample unit for this examination shall be one filled primary container. The average net contents shall be not less than the specified or indicated quantity.

S1.1.2.3 Inspection levels for examinations. The inspection levels for determining the sample size and acceptance shall be as specified in Table S1.2.

S1.1.2.4 Examination for workmanship. For the examination for conformance to Section 8, the sample unit shall be one bag of dry mortar or one drum of wet mortar, as applicable. The
examination may be made during selection of samples for testing or other examinations. For each lot, select a sample size of five. Reject the lot on one failure.

S1.2 Tests:
S1.2.1 For the tests specified in 11.1 through 11.4, the inspection level for determining sample size shall be S1 in accordance with MIL-STD-105.

### TABLE S1.2 Inspection Levels for Examinations

<table>
<thead>
<tr>
<th>Examination</th>
<th>Lot Size</th>
<th>Sample</th>
<th>Accept</th>
<th>Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1.1.2.1</td>
<td>2 to 500</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>501 to 35,000</td>
<td>20</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>35,001 to 500,000</td>
<td>32</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>over 500,000</td>
<td>50</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>S1.1.2.2</td>
<td>less than 35,000</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>more than 35,000</td>
<td>20</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

S1.3 Preparation for Delivery:
S1.3.1 Type 1, Dry Mortar:
S1.3.1.1 Levels A and B—Type 1 mortar shall be packed in 100-lbs (45-kg) unit quantity in multiwall shipping sacks conforming to UU-S-48 or PPP-B-35.

S1.3.2 Type 2, Wet Mortar:
S1.3.2.1 Levels A and B—Type 2 mortar shall be packed in steel drums conforming to Type II of PPP-B-704, except that use of 22-gage steel drums of 12-gal (44-L) capacity is acceptable. Dropside handles shall be provided.

S1.3.3 Marking—In addition to any special marking required by the contract or purchase order, shipping containers shall be marked for shipment in accordance with MIL-STD-129.
Standard Specification for
Envelope Dimensions for Butterfly Valves—NPS 2 to 24

1. Scope

1.1 This specification provides standard dimensions for manual (lever and gear actuator) butterfly valves installed in shipboard piping systems in NPS 2 to NPS 24, inclusive.

1.2 This specification covers conventional and ANSI B16.34 class butterfly valves of both lug and wafer types.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ANSI Standard:
B 16.34 Small Butt Welding End Valves

3. Dimensions

3.1 Face-to-Face Dimensions:
3.1.1 Valve body face-to-face dimensions are provided in Table 1.

3.1.2 Face-to-face dimensions are the metal-to-metal dimensions between the valve body flange faces that require separate gaskets or the compressed or installed condition for valves using liners that extend from the body contact faces and act as flange gaskets.

3.2 Actuator Dimensions:

3.2.1 The maximum permissible dimensions for lever- and gear-type actuators are provided in Fig. 1.
3.2.2 The handwheel and handle may be on either side of the valve.
3.2.3 All handwheels and handles rotate clockwise to close the valve.

4. Tolerances

4.1 Face-to-Face Dimensions—A plus or minus tolerance of 1/16 in. (1.6 mm) for all sizes shall be allowed (see Table 1).

5. Keywords

5.1 envelope dimensions; gear actuator butterfly valves; lever butterfly valves; manual butterfly valves

TABLE 1 Face-to-Face Dimensions

<table>
<thead>
<tr>
<th>Valve Size, NPS</th>
<th>Conventional, 200 psig, in. (mm)</th>
<th>ANSI B16.34, 150 Class, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1 1/2 (41)</td>
<td>1 1/4 (44)</td>
</tr>
<tr>
<td>2 1/2</td>
<td>1 1/4 (44)</td>
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<td>3</td>
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<td>2 1/4 (57)</td>
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<tr>
<td>10</td>
<td>2 1 1/8 (65)</td>
<td>2 1 1/8 (71)</td>
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<tr>
<td>12</td>
<td>3 1/8 (76)</td>
<td>3 5/8 (81)</td>
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<td>14</td>
<td>3 5/8 (81)</td>
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</tr>
<tr>
<td>16</td>
<td>4 1/8 (105)</td>
<td>4 (102)</td>
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<tr>
<td>18</td>
<td>4 1/8 (102)</td>
<td>4 1/8 (104)</td>
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<tr>
<td>20</td>
<td>5 1/8 (128)</td>
<td>5 (127)</td>
</tr>
<tr>
<td>24</td>
<td>5 1/8 (127)</td>
<td>6 1/8 (154)</td>
</tr>
</tbody>
</table>
TABLE 1

<table>
<thead>
<tr>
<th>Dimensions, in.</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
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<td>A</td>
<td>8.00</td>
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</tr>
</tbody>
</table>

FIG. 1 Actuator Envelope Dimensions

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Standard Specification for Rat Guards, Ship’s (Metric)\(^1\)

This standard is issued under the fixed designation F 1099M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the materials, dimensions, and assembly of steel and aluminum rat guards.

1.2 Rat guards are intended to prevent rats from boarding ships by way of mooring lines.

1.3 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

- A 525M Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) By the Hot-Dip Process (Metric)\(^2\)
- B 209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)\(^3\)

3. Classification

3.1 Rat guards shall be classified into three types as follows:

3.1.1 Type I—Multiple-line (doubling up), self-adjustable, accommodating the mooring line combinations listed in Table 1.

3.1.2 Type II—Single-line, self-adjustable, accommodating a single 5-mm wire to a 76-mm-diameter mooring line.

3.1.3 Type III—Conical shape with tapered, slotted sleeve.

Type III rat guards shall be of the following sizes: (a) 75 mm, (b) 125 mm and (c) 200 mm.

3.2 Types I and II rat guards (see 3.1.1 and 3.1.2) are designed to be installed from the deck or pier without a person physically coming in contact with the mooring lines or hawser, by lowering and positioning the guards away from the ship’s hull with two ropes that are permanently attached as guide and tie ropes (see Fig. 1).

3.3 Type III rat guards (see 3.1.3) require a person to contact the mooring line to pull the two halves of the conical guard around the mooring line, wrap the slotted sleeves (see Fig. 2) to the line, and physically close any opening between the mooring line and the circular opening at the center of the guard.

4. Ordering Information

4.1 Orders for rat guards under this specification shall include the following information:

4.1.1 ASTM designation.

4.1.2 Type required (see 3.1):

4.1.2.1 If Type III, material required (see 5.1.3).

4.1.2.2 If Type III, size required (see 3.1.3).

4.1.3 Quantity required.

4.1.4 Optional requirements, if any (see Supplementary Requirements S1 through S3).

5. Materials and Manufacture

5.1 Materials:

5.1.1 Type I rat guards shall be made of aluminum-alloy sheet metal conforming to the requirements of ASTM Specification B 209M, 6061-T6, or 5052-H32.

5.1.2 Type II rat guards shall be made of galvanized sheet steel conforming to the requirements of ASTM Specification A 525M, Coating Designation 450. The coating shall be a minimum of 450 g/m\(^2\) in accordance with the triple-spot test of ASTM Specification A 525M.

5.1.3 Type III rat guards shall be made of either of the materials specified in 5.1.1 and 5.1.2 (see 4.1.2.1).

5.2 Manufacture:

5.2.1 Types I and II rat guards shall be provided with the following:

5.2.1.1 Hinge Bolt—A M 7 × 1 hexagon head bolt 20 mm long with elastic stop nut and washer. All parts shall be corrosion-resistant steel.

5.2.1.2 Guide and Tie Rope—Polyester or nylon of good commercial quality, 6- or 9-mm diameter by 6 m long.

---

TABLE 1 Mooring Line Combinations for Type I Rat Guards

<table>
<thead>
<tr>
<th>Mooring Lines Diameter, mm</th>
<th>Number of Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 wire</td>
<td>as required</td>
</tr>
<tr>
<td>25-33 line</td>
<td>3 or more</td>
</tr>
<tr>
<td>41-50 line</td>
<td>3</td>
</tr>
<tr>
<td>50-82 line</td>
<td>2</td>
</tr>
</tbody>
</table>

---

\(^1\) This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

\(^2\) Annual Book of ASTM Standards, Vol 01.06.

\(^3\) Annual Book of ASTM Standards, Vol 02.02.
5.2.1.3 **Grommet**—Good commercial quality brass and of size suitable for the guide and tie ropes.

5.2.2 **Type III Rat Guards**—Type III rat guards shall consist of two half disks and two half tapered sleeves. Both halves shall be identical except one half shall be provided with a “U” shaped sleeve.

5.2.2.1 The hinge bolt provided with each rat guard shall consist of a commercial M 7 × 1 hexagon head bolt, 20-mm-long nut, and washer. All parts shall be corrosion-resistant steel.

5.2.2.2 The galvanized steel or aluminum sleeve shall be slotted as specified in Table 2 and Fig. 2, so that when the rat guard is in place, it may be drawn tightly against the hawser, with lashing. The formed sleeves shall be tapered to permit nesting of the rat guards, for compact shipping.

5.2.2.3 When the rat guard is made of galvanized steel, the sleeve shall be riveted and soldered to the disk with tinner’s type rivets, No. 3, 4-mm diameter for each half sleeve. The number of rivets shall be the same as the number of prongs. Soldering of the half sleeve flange to the half disk shall be continuous, inside and outside (see Fig. 2).

### TABLE 2 Dimensions for Type III Rat Guards

<table>
<thead>
<tr>
<th>Size</th>
<th>Diagonal (see Fig. 2), mm</th>
<th>Number of Prongs in Complete Sleeve (See 5.2.2.2)</th>
<th>Thickness of Disk, Sleeve, and Guide, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>75</td>
<td>1000</td>
<td>6</td>
</tr>
<tr>
<td>125</td>
<td>125</td>
<td>1300</td>
<td>10</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
<td>1300</td>
<td>16</td>
</tr>
</tbody>
</table>
5.2.2.4 When the rat guard is made of aluminum alloy sheets, the sleeve shall be spot welded and riveted to the disk. Spacing of spot welds shall not exceed 50 mm with a minimum of four spot welds provided on each half of the rat guard. The rivets shall be equivalent to No. 3, 4-mm diameter. Five rivets shall be installed in each half of the guard. Rivets shall be located equidistant, between adjacent spot welds (see Fig. 2).

6. Dimensions and Permissible Variations

6.1 Dimensions of Type I rat guards ±6 mm shall be as follows:

6.1.1 Overall height shall be 1000 mm.
6.1.2 Overall thickness shall be 40 mm maximum.

6.2 Dimensions of Type II rat guards ±6 mm shall be as follows:

6.2.1 Overall length shall be 1000 mm.
6.2.2 Overall thickness shall be 40 mm maximum.
6.3 Dimensions of Type III rat guards shall be as specified in Table 2 and Fig. 2.

7. Workmanship, Finish, and Appearance

7.1 Workmanship shall be of the highest quality throughout and in conformance with the accepted commercial standard practice for this type of equipment.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order (see 4.1.4).

S1. Referenced Documents

S1.1 The following documents are applicable only when the requirements of S3 are specified in the contract or purchase order (see 4.1.4).

S1.1.1 Military Standards:
MIL-STD-129 Standard for Marking for Shipment and Storage
MIL-C-52950 Specification for Crates, Wood, Open, and Covered

S1.1.2 Federal Standards:
PPP-B-601 Specification for Boxes, Wood, Cleated-Plywood
PPP-B-621 Specification for Boxes, Wood, Nailed and Lock Corner
PPP-T-97 Specification for Tape, Packaging/Individual, Filament Reinforced

S1.1.3 Official Classification Committee Standard:
Uniform Freight Classification Ratings, Rules, and Regulations

S1.1.4 National Motor Freight Traffic Association Standard:


TABLE S1.1 Sampling for Examination and Trial Assembly

<table>
<thead>
<tr>
<th>Number of Rat Guards in Lot</th>
<th>Number of Rat Guards in Sample</th>
<th>Acceptance Number (Defective)</th>
<th>Rejection Number (Defective)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 and under</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>26 to 40</td>
<td>7</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>41 to 65</td>
<td>10</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>66 to 110</td>
<td>15</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>111 to 300</td>
<td>25</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>301 to 800</td>
<td>35</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

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4 Available from Standardization Documents, Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPQDS.
6 Available from Uniform Classification Committee Agent, Tariff Publication Officer, Room 1106, 222 S. Riverside Plaza, Chicago, IL 60606.
S2.1.2.2 Table S1.1 shall be applied separately to major and minor defects (see Table S2.1) for purpose of lot acceptance and rejection.

S2.2 Examination—Rat guards selected in accordance with S2.1.2 shall be examined as specified in Table S2.1 and measured to verify conformance to the requirements of this specification.

S2.3 Trial Assembly—Rat guards selected in accordance with S2.1.2 shall be assembled in the specified dimensional size to verify conformance with the functional requirements of this specification.

S2.4 Inspection of Packaging—Sample packages and packs, and the inspection of the preservation-packaging, packing, and product marking for shipment and storage shall be in accordance with the requirements of Sections 8, 9, and S3, and the documents specified therein.

**S3. Packaging and Package Marking**

**S3.1 Preservation (Type III only)—**Preservation shall be Level A or C, as specified (see 4.1.4).

**S3.1.1 Level A:**
- Preservatives shall not be used.

**S3.1.2 Level B**—Rat guards selected in accordance with S2.1.2 shall be nested together by disassembling each guard and securing the two halves together at the funnel with filament reinforced pressure sensitive tape conforming to PPP-T-97. The hinge bolt, nut, and washer for each guard shall be secured to one half of the guard to prevent loss or damage.

**S3.2 Level C**—Rat guards, assembled or disassembled at the contractor’s option, shall be unit packed to afford protection against damage during shipment from the supply source to the first using activity for immediate use. The contractor’s retail or wholesale preservation methods may be used when such meets the requirements of this level.

**S3.2.1 Level A**—Eight rat guards (for Type III, eight disassembled rat guards) unit packed as specified in S3.1 shall be packed in wood cleated plywood, nailed wood, or open wood crates conforming to PPP-B-601 overseas type, PPP-B-621 class 2, or MIL-C-52950 boxes or crates respectively. Selection of the box or crate shall be at the option of the contractor. Protection shall be provided by means of blocking, bracing, or cushioning, or other media to prevent damage during handling, shipment, and storage.

**S3.2.2 Level B**—Eight rat guards (for Type III, eight disassembled rat guards) unit packed as specified in Level A, except that containers shall conform to the domestic class or grade of the type used.

**S3.2.3 Level C**—Packing shall be accomplished in a manner that will ensure acceptance by common carrier at the lowest rate and will afford protection against physical or mechanical damage during direct shipment from the supply source to the using activity for early installation. The shipping containers or method of packing shall conform to the Uniform Freight Classification Rules, National Motor Freight Classification, or other carrier regulations, as applicable to the mode of transportation.

**S3.3 Product Marking**—In addition to any special marking required (see 4.1.4), unit packs and shipping containers shall be marked in accordance with MIL-STD-129. Unit packs in open crates shall be marked with waterproofed tags.

**S3.3.1** When specified (see 4.1.4), manufacturers shall assign a part number containing a five digit numeral manufacturer’s code as assigned by the U.S. government under the Federal Cataloging Program.

**S3.3.2** When specified (see 4.1.4), the marking specified in 8.1 shall include a National Stock Number.

**Note:** The packaging requirements specified apply only for direct government acquisition.

---

**TABLE S2.1 Classification of Defects (Applicable to All Types of Rat Guards, Unless Otherwise Specified)**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical:</td>
<td>None defined</td>
</tr>
<tr>
<td>Major:</td>
<td>At trial assembly (see S2.3) guard does not fit properly over specified hawser sizes.</td>
</tr>
<tr>
<td>101</td>
<td>Guard does not maintain a secure and correct position when lashed to the hawser (see Fig. 2).</td>
</tr>
<tr>
<td>102</td>
<td>Thickness of material not as specified (see Section 6).</td>
</tr>
<tr>
<td>103</td>
<td>Sleeves not tapered to allow for nesting closely for shipment, Type III only (see 5.2.2.2).</td>
</tr>
<tr>
<td>104</td>
<td>Sleeves or guide not properly assembled as specified in 5.2.1 and Fig. 1 or 5.2.2 and Fig. 2 as applicable.</td>
</tr>
<tr>
<td>105</td>
<td>Rat guard is warped.</td>
</tr>
<tr>
<td>106</td>
<td>Galvanizing is less than 450 g/m² for Types II and III rat guards (see 5.1.2 and 5.1.3).</td>
</tr>
<tr>
<td>Minor:</td>
<td>Dimensions do not conform to 6.1, 6.2, and 6.3.</td>
</tr>
<tr>
<td>201</td>
<td>Bolt, nut, and washer not as specified in 5.2.1.1 and 5.2.2.1.</td>
</tr>
<tr>
<td>202</td>
<td>Outside edges sharp or inside of rat guard rough.</td>
</tr>
<tr>
<td>203</td>
<td>Galvanizing not uniform.</td>
</tr>
</tbody>
</table>

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4
Standard Specification for
Warping Heads, Rope Handling (Gypsy Head, Capstan Head) ¹

1. Scope
1.1 This specification covers warping heads used with windlass, winch, and capstan drive units to pull rope on board ships. Warping heads are primarily for use with fiber rope, natural, or synthetic.
1.2 Warping heads with external ribs or whelps on the barrel, notched flanges, attached storage drums, unfinished drums, or non heat-treated fabrications, are considered special and are permitted within the scope of this specification when fully described under special ordering information.
1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents
2.1 ASTM Standards:
A 27/A 27M Specification for Steel Castings, Carbon, for General Application ²
A 36/A 36M Specification for Carbon Structural Steel ³
A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless ⁴
A 148/A 148M Specification for Steel Castings, High-Strength, for Structural Purposes ²
A 501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing ⁴
A 724/A 724M Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels ³
A 735/A 735M Specification for Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service ³
E 10 Test Method for Brinell Hardness of Metallic Materials ⁵
2.2 AWS Standard:
D 1.1 Structural Welding Code ⁶
2.3 ANSI Standard:
ASA B 46.1 Surface Texture ⁷
2.4 Military Standards:
Fed-Spec T-R-605 Manila, Three Strand ⁸
MIL-R-24050 Nylon, Double Braided ⁸

3. Definitions of Terms Specific to This Standard
3.1 barrel—cylindrical or conical midbody portion of a warping head.
3.1.1 Discussion—The barrel may have a uniform diameter through the length or may be tapered from one end to the other.
3.2 flanges—circumferential rims at the ends of the barrel used to retain wraps of rope on the barrel portion of the warping head.
3.3 rope contact surfaces—portions of the barrel, flanges, and connecting fillets that a rope will contact when led in tangent to the barrel and normal to the shaft centerline, wrapped around the barrel, and led away tangent to the barrel as in normal use. (See Fig. 1 and Fig. 2.)
3.4 warping head (also known as a gypsy head or capstan head)—cylindrical or conical rotating member to receive multiple wraps of rope around the circumference of the member and of suitable strength to impart a pulling motion to the rope by friction contact when the member is rotated.

4. Classification
4.1 The size of the warping head shall be identified by the nominal barrel diameter measured at the smallest point of the barrel.
4.2 Warping heads under this specification are furnished in two types as follows:
4.2.1 Type I Warping Head With Cylindrical Barrel—Generally used in but not restricted to horizontal shaft applications. Also known as a gypsy head (see Fig. 1).

¹ This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.
² Annual Book of ASTM Standards, Vol 01.02.
⁴ Annual Book of ASTM Standards, Vol 01.01.
⁵ Annual Book of ASTM Standards, Vol 03.01.
4.2.2 Type II Warping Head With a Conical Barrel—Mounted with the large end of the barrel toward the drive machinery. Generally used in but not restricted to vertical shaft applications. Also known as a capstan head (see Fig. 2).

4.3 Warping heads are divided into four grades as follows:

4.3.1 Grade 1—Fabricated from any combination of structural steel plate, pipe, tubing, or steel castings and joined by electric welding.

4.3.2 Grade 2—Cast from mild to medium strength steel.

4.3.3 Grade 3—Fabricated from any combination of steel plate or steel castings and joined by electric welding. Heat treated to provide a surface hardness (1/8 in. (3 mm) deep) of 200 to 250 Brinell on rope contact surface. Rope contact surface finished to an average 125- to 160-µin. (3175- to 4064-µmm) finish.

4.3.4 Grade 4—Cast from high strength steel castings and heat treated to provide a surface hardness (1/8 in. (3 mm) deep) of 200 to 250 Brinell on rope contact surface. Rope contact surface finished to an average 125- to 160-µin. (3175- to 4064-µmm) finish.

4.4 When required by ordering information, an accessory cover will be provided to cover the open end of the warping head.

5. Ordering Information

5.1 Orders for warping heads under this specification shall include the following:

5.1.1 Quantity (number),
5.1.2 ASTM designation and year of issue,
5.1.3 Size (barrel diameter),
5.1.4 Type (I or II),
5.1.5 Grade (1, 2, 3, or 4),
5.1.6 As-cast or machined dimensions for warping head bore, hub length and location, hub puller holes, and shaft keying,
5.1.7 Requirement for optional accessory cover on open end of warping head (see 4.4),
5.1.8 Special features required (ribs or whelps on barrel, notched flanges, and attached storage drums), and
5.1.9 Product marking (shipping).

6. Material and Manufacture

6.1 Material for Grade 1 warping heads shall conform to Specification A 36/A 36M or Specification A 27/A 27M for barrel, flanges, hubs, and structural webs or diaphragms. Materials conforming to Specifications A 53 or A 501 may be used as an alternate for the barrel. Component parts may be formed by rolling or flanging, and joined by electric welding in accordance with ASW D1.1. Warping head weldment shall be stress relieved.

6.2 Material for Grade 2 warping heads shall conform to Specification A 27/A 27M annealed.

6.3 Material for Grade 3 warping heads shall conform to Specifications A 148/A 148M, A 724/A 724M Grade B, or Specification A 735/A 735M Class 4. Component parts may be formed by casting, rolling or flanging, and joined by electric welding, in accordance with AWS D1.1. Warping head weldment shall be stress relieved and heat treated for a surface hardness (1/8 in. (3 mm) deep) of 200 to 250 Brinell on rope contact surface. Rope contact surface finished to an average 125- to 160-µin. (3175- to 4064-µmm) finish.

6.4 Material for Grade 4 warping heads shall conform to Specification A 27/A 27M annealed.

6.5 When required by ordering information, an accessory cover will be provided to cover the open end of the warping head.

6.6 When required by ordering information, an accessory cover will be provided to cover the open end of the warping head.
hardness (1/8 in. (3 mm) deep) of 200 to 250 Brinell on rope contact surface, in accordance with hardness Test Method E 10. Rope contact surfaces shall be finished in accordance with 8.7.

6.4 Material for Grade 4 warping heads shall conform to Specification A 148/A 148M quenched and tempered for a surface hardness (1/8 in. (3 mm) deep) of 200 to 250 Brinell on rope contact surface in accordance with hardness Test Method E 10. Rope contact surfaces shall be finished in accordance with 8.7.

6.5 The manufacturer’s name or identification mark, ASTM specification number, and pattern, part, or drawing number shall be cast molded or die stamped on the warping head, using minimum 1/2 -in. (13-mm) size characters. The marking shall not be on the rope contact surface and shall be readily available for identification on an assembled windlass, winch, or capstan.

6.6 Structural webs and diaphragms between the hub and barrel shall completely seal and void internal portions of the warping head against the entry of water or provide complete self-drainage and maintenance access to internal portions. When present, voids shall be treated with preservative or primer paint.

6.7 An accessory cover, when required by the purchase order, shall be provided to cover the open end of the warping head opposite the drive shaft. Material shall be cast or wrought, steel or bronze. The cover shall be flat or domed and attached with corrosion-resistant fasteners (brass or monel), without projections that could snag or cut a slack rope and with provision for locking to prevent loosening under vibration. When the cover forms a void, a gasket shall be provided to seal against the entry of water.

7. Dimensions, Mass, and Permissible Variations

7.1 Principal dimensions, tolerances, and strength requirements for Types I and II are shown in Fig. 1 and Fig. 2, respectively. These requirements are considered standard and will govern unless special features are required and described (see 5.1.8).

7.2 Commonly acceptable warping head sizes for various fiber ropes are shown in Table 1 for general guidance only. The use of five wraps when using manila fiber rope is accepted practice. Some synthetic fiber ropes, because of reduced friction, require additional wraps. The equivalent sizes of synthetic fiber ropes shown in Table 1 are reduced on the basis of breaking strength and provide additional space on the barrel for increased wraps.

7.3 The strength of the barrel, flanges, webs, and diaphragms shall withstand the maximum rope pull shown in Fig. 1 and Fig. 2, applied tangent to the barrel, normal to the shaft, at the midpoint of the barrel, and wrapped around the barrel, with the combined stress not exceeding 75 % of the tensile yield point of the material. Compressive forces on the barrel, torsional shear forces between hub and barrel, and the wedging forces against the flanges, shall be considered. This requirement does not imply a similar requirement for drive horsepower or brake capacity in the drive unit.

8. Workmanship, Finish, and Appearance

8.1 Welds shall be extended around ends of members and be free of pockets and irregularities that would tend to trap water.

8.2 Welds shall be ground flush to match the surrounding surface in areas of rope contact.
8.3 Component parts, formed by rolling or flanging, shall be visually examined during fabrication to ensure freedom from cracks.

8.4 Castings shall be smooth, of fine grain, and free of cracks, hot tears, and blow holes, detrimental to end use.

8.5 Castings shall have all flash material, vents, and gates removed and ground flush to match the surrounding surfaces.

8.6 Weldments and castings shall be free of sharp edges and burrs that could cut or snag fiber rope coming in contact with any accessible portion of the rotating warping head.

8.7 Rope contact surfaces of Grades 3 and 4 warping heads shall be finished to an average surface roughness of 125 to 160 µin. (3175 to 4064 µmm) in accordance with ANSI Standard ASA B46.1.

Note 1—Local flaws (holes) no larger than ³⁄₈ in. (4.7 mm) in diameter are acceptable when they have no sharp edges or burrs that would cut fiber rope, providing the total area of flaws (holes) does not exceed 5% of the total rope contact surface.

8.8 Weldments and castings shall be cleaned by sand blasting, shot blast, or equivalent methods to remove all loose scale or slag.

9. Inspection

9.1 The completed warping head shall be visually inspected for workmanship, dimensions, surface hardness (when applicable), finish and appearance, after cleaning.

10. Product Marking

10.1 Shipping—Each warping head, when furnished as a separate component, shall be marked with the ASTM standard designation, type and grade, purchase order, and item number. Product marking shall be by paint or weatherproof tag.

11. Packaging and Package Marking

11.1 Warping heads, when furnished as a separate component, shall be crated, skidded, or attached to a pallet in a manner acceptable for handling by common carrier. When warping head is furnished with machined bore or hub, machined surfaces shall be protected against corrosion in open weather storage for a period of at least one year.

12. Keywords

12.1 berthing ship; capstan drive units; capstan head; capstan windlass; gypsyhead; mooring ship; rope handling; warping head winch; warping ship; windlass

### TABLE 1 Warping Head Size and Suggested Rope Size

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>12.5</td>
<td>⁵⁄₄ – 2</td>
<td>³⁄₄ – 2</td>
</tr>
<tr>
<td>9</td>
<td>25.0</td>
<td>⁷⁄₈ – 3</td>
<td>⁵⁄₈ – 3</td>
</tr>
<tr>
<td>12</td>
<td>37.5</td>
<td>³⁄₄ – 4</td>
<td>³⁄₄ – 4</td>
</tr>
<tr>
<td>15</td>
<td>50.0</td>
<td>⁴⁄₅ – 5</td>
<td>⁴⁄₅ – 5</td>
</tr>
<tr>
<td>18</td>
<td>75.0</td>
<td>⁵⁄₆ – 6</td>
<td>⁵⁄₆ – 5</td>
</tr>
<tr>
<td>21</td>
<td>100.0</td>
<td>⁶⁄₇ – 7</td>
<td>⁶⁄₇</td>
</tr>
<tr>
<td>24</td>
<td>125.0</td>
<td>⁷⁄₈ – 8</td>
<td>⁶⁄₈</td>
</tr>
<tr>
<td>27</td>
<td>150.0</td>
<td>⁸⁄₉ – 9</td>
<td>⁸⁄₉</td>
</tr>
<tr>
<td>30</td>
<td>175.0</td>
<td>10</td>
<td>⁷⁄₈</td>
</tr>
<tr>
<td>33</td>
<td>200.0</td>
<td>11</td>
<td>⁸</td>
</tr>
<tr>
<td>36</td>
<td>225.0</td>
<td>12</td>
<td>⁸⁄₉ – 9</td>
</tr>
</tbody>
</table>

Notes:

1. The following table is provided for guidance subject to variations in breaking strengths and friction characteristics of specific ropes. Breaking strengths of ropes used should not exceed the maximum rope pull shown for the warping head size selected.

2. Other rope constructions and materials are not listed in the absence of recognized standard breaking values.

3. 1 in. = 25.4 mm.

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Standard Specification for
Circular Metallic Bellows Type Expansion Joints for Piping Applications

This standard is issued under the fixed designation F 1120; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification establishes the minimum requirements for the mechanical design, manufacture, inspection, and testing of circular metallic bellows-type expansion joints used to absorb the dimensional changes resulting from piping thermal expansion or contraction, as well as the movement of terminal equipment and supporting structures.
1.2 Additional or better features, over and above the minimum requirements set by this specification, are not prohibited by this specification.
1.3 The layout of many piping systems provides inherent flexibility through natural changes in direction so that any displacements produce primarily bending or torsional strains, within acceptable limits. Where the system lacks this inherent flexibility the designer should then consider adding flexibility through the use of metallic bellows-type expansion joints.
1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents
2.1 ANSI Standards:
B16.5 Pipe Flanges and Flanged Fittings
B16.25 Butt Welding Ends
B31.1 Power Piping Code
2.2 ASME Standards:
Section VIII, Division 1, Pressure Vessels
Section IX, Welding and Brazing Qualifications
2.3 EJMA Standard:
Standards of the Expansion Joint Manufacturer’s Association

2.4 Pipe Fabrication Institute Standard:
ES-3 Fabrication Tolerances

3. Terminology Definitions
3.1 Expansion joint definitions shall be in accordance with those in the EJMA standards.
3.2 double expansion joint—expansion joint consisting of two bellows joined by a common connector.
3.3 Discussion—The common connector is anchored to some rigid part of the installation by means of an anchor base. The anchor base may be attached to the common connector either at installation or at time of manufacture. Each bellows acts as a single expansion joint and absorbs the movement of the pipe section in which it is installed independently of the other bellows.
3.4 gimbal expansion joint—expansion joint designed to permit angular rotation in any plane by the use of two pairs of hinges affixed to a common floating gimbal ring.
3.5 Discussion—The gimbal ring, hinges, and pins are designed to restrain the thrust of the expansion joint as a result of internal pressure and extraneous forces, where applicable.
3.6 hinged expansion joint—expansion joint containing one bellows designed to permit angular rotation in one plane only by the use of a pair of pins through hinge plates attached to the expansion joint ends.
3.7 Discussion—The hinges and hinge pins are designed to restrain the thrust of the expansion joint as a result of internal pressure and extraneous forces. Hinged expansion joints should be used in sets of two or three to function properly.
3.8 pressure balanced expansion joint—expansion joint designed to absorb axial movement or lateral deflection, or both, while restraining the pressure thrust by means of tie devices interconnecting the flow bellows with an opposed bellows also subjected to line pressure.
3.9 Discussion—This type of expansion joint is intended for use where a change of direction occurs in a run of piping. The flow end of a pressure balanced expansion joint sometimes

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3 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.
4 Available from Expansion Joint Manufacturer’s Association, 25 N. Broadway, Tarrytown, NY 10591. The Standards of the Expansion Joint Manufacturer’s Association are a collection of standards developed by this industry and published in one volume, herein called EJMA Standards.
5 Available from Pipe Fabrication Institute, 1326 Freeport Rd., Pittsburgh, PA 15238.
contains two bellows separated by a common connector, in which case it is called a universal pressure balanced expansion joint.

3.10 single expansion joint—simplest form of expansion joint, consisting of single bellows construction, designed to absorb all movement of the pipe section in which it is installed.

3.11 swing expansion joint—expansion joint designed to absorb lateral deflection or angular rotation, or both, in one plane.

3.12 Discussion—Pressure thrust and extraneous forces are restrained by the use of a pair of swing bars, each of which is pinned to the expansion joint ends.

3.13 universal expansion joint—expansion joint containing two bellows joined by a common connector for the purpose of absorbing any combination of axial movement, lateral deflection, and angular rotation.

3.14 Discussion—Universal expansion joints are usually furnished with control rods to distribute the movement between the two bellows of the expansion joint and stabilize the common connector.

4. Ordering Information

4.1 An expansion joint is a unique product and must be specifically designed for the intended service. It is the responsibility of the piping system designer to supply sufficient engineering data necessary for the complete design. The information compiled by the piping system designer must be complete and contain all pertinent data detailing the conditions under which the expansion joint is expected to operate.

4.2 Orders for each expansion joint shall include the following information:

4.2.1 Title, designation number, and latest revision of this specification.

4.2.2 Size—The nominal pipe diameter or specific ducting diameter.

4.2.3 Type of Expansion Joint—single, double, universal, guided, hinged, gimbal, swing, or pressure balanced.

4.2.4 Flow Characteristics:

4.2.4.1 Flow Medium—indicate whether the medium is gas or liquid.

4.2.4.2 Flow velocity, medium density, or viscosity, or combination thereof.

4.2.4.3 Flow direction.

4.2.5 Pressure in psig (N/mm²)—design, operating, and test pressures.

4.2.6 Temperature in °F (°C)—design, operating, and installation temperatures.

4.2.7 Movement—axial (extension, compression); lateral (single plane, multiplane); angular; torsional (to be avoided). Differentiate between start-up, operational, or field installation tolerance movements.

4.2.8 Materials—Material types (including that for the bellows) shall be specified by the purchaser (see 5.1 for material restrictions).

4.2.9 Internal Liner—Liner shall be specified when needed because of flow velocity or other flow conditions. Specific criteria for liners is shown in Section C-3 of the EJMA Standards (see 6.6).

4.2.10 External Cover—To protect personnel having close access to the bellows, when thermal insulation is to be added in the field, or when external mechanical damage is possible (see 6.5).

4.2.11 End Fittings—The type of end connections such as flanged, threaded, or others to match the mating piping or terminal equipment.

4.2.12 Accessories—Specify what accessories are required and the conditions under which they operate. Consider items such as insulation lugs, tie, limit, or control rods, pantographic linkages, trunnions, gimbal, drains, purge connections, anchor bases, and interply monitoring devices.

4.2.13 Dimensional Limitations—If space limitations exist, specify the maximum overall length, maximum outside diameter, minimum inside diameter, and installation tolerances.

4.2.14 Operating Forces—Specify calculated bellows spring forces and pressure thrust forces if they are required for subsequent anchor design or other piping systems analysis. If there are maximum allowable values, these must also be specified.

4.2.15 Installation Position—horizontal, vertical (flow up or down). Specify if liner drainage holes are required.

4.2.16 Cycle Life Requirements—Specify an anticipated number of thermal cycles over the intended life of the expansion joint.

4.2.17 Testing Requirements—Specify testing requirements in addition to the hydrostatic test required by 9.4 (for example, vacuum testing, testing at operating temperature).

4.2.18 Inspection Requirements—Specify inspection requirements in addition to the inspection required by Section 9 (that is, radiographic, fluorescent penetrant, or mass spectrometer).

4.2.19 Piping Code Requirements—Specify any piping or design code that must be used as the basis for design in addition to those specified in 5.2.

4.2.20 Special Requirements—Specify the magnitude of special system conditions such as vibration, shock, or hydraulic surge.

4.2.21 Shipping Requirements—Specify whether special packing is required including protection for extended outside storage, export handling, or special lifting considerations for heavy or large assemblies.

4.2.22 Piping Drawing—In addition to specifying the above information it would be beneficial to provide a drawing of the proposed piping system.

4.2.23 Supplementary Requirements—Specify any additional requirements not identified herein.

4.3 Fig. 1 and Fig. 2 should be used as a guide in ordering expansion joints to this specification.

5. Materials and Manufacture

5.1 Materials:

5.1.1 Pressure-containing parts shall be manufactured from material specifications and grades listed in Section VIII, Division 1, of the ASME Code or ANSI B31.1. End connection material shall have in service properties similar to the bellows material. Flanges shall meet ANSI B16.5.

5.1.2 All other materials of construction shall be of the type specified by the user and shall conform to an ASTM or ASME
### FIG. 1 Standard Expansion Joint Specification Sheet

<table>
<thead>
<tr>
<th>ITEM NO./EJ TAG NO.</th>
<th>DESCRIPTION</th>
<th>REFERENCE</th>
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<tr>
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<tr>
<td>2</td>
<td>NOMINAL SIZE/I.D./O.D. (IN.)</td>
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<td>3</td>
<td>EXPANSION JOINT TYPE</td>
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<td>4b</td>
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<tr>
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<tr>
<td>19</td>
<td>VIBRATION AMPLITUDE/FREQUENCY</td>
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**Note:** The table continues with more entries, providing detailed specifications for expansion joints, such as design pressures, test pressures, maximum installation movements, maximum design movements, operating fluctuations, materials of construction, and quality assurance requirements. The table is comprehensive, covering aspects from temperature and pressure specifications to structural and installation details, ensuring a thorough understanding of the joint specifications as per the standard F 1120 – 87 (1998).
FIG. 2 Supplemental Specification Sheet (To Be Used With Standard Expansion Joint Specification Sheet)
material specification. Materials not identified by the ordering data shall be of the manufacturer’s standard and of the same quality used for the intended purpose in commercial practice.

5.1.3 Materials used shall be free from defects that would adversely affect the performance of the expansion joint.

5.1.4 All material incorporated in the work covered by this specification shall be new. The use of rebuilt or used products is not allowed under this specification.

5.1.5 Materials for hinge or gimbal hardware, or other sliding parts, shall be chosen to minimize galling of the contacting parts.

5.2 Manufacture:

5.2.1 Expansion joints shall be designed and fabricated in accordance with requirements set forth in the ordering data and the EJMA Standards.

5.2.2 Nonstandard flanges shall be designed and fabricated in accordance with Appendix 2 of Section VIII, Division 1, of the ASME Code. Flanges machined from plate shall not be used at pressures exceeding 150 psi (1034 kPa) and temperatures exceeding 450°F (232°C). Hubbed flanges machined from plate or bar stock shall meet the requirements of Appendix 2, Paragraph 2-2(d) of Section VIII, Division 1, of the ASME Code.

5.2.3 All welding shall be accomplished in accordance with ANSI B 31.1.

5.2.4 Welding personnel and welding procedures shall be qualified in accordance with the applicable sections of Section IX of the ASME Code.

5.2.5 All fabrication details not covered by the referenced codes and standards shall be taken from the appropriate ANSI standard. If no standard applies, accepted industry practice shall govern.

5.2.6 The bellows shall be of tested and proven convolution geometry.

6. Other Requirements

6.1 The details of design, material supply, fabrication, and testing of the complete product are the responsibility of the manufacturer unless specific details are requested by the purchaser.

6.2 The specified normal operating movements (axial, lateral, and angular) shall be available concurrently. The specified lateral and angular movements shall be available on either side of the expansion joint centerline.

6.3 Internal sleeves, external covers, and all attached hardware shall be constructed so as not to interfere with adjacent parts when the joint is in the fully deflected position.

6.4 Universal expansion joints shall be designed and fabricated to be self-supporting and not require any external structure for the support of the center pipe spool piece and its contents.

6.5 Expansion joints to be installed in systems above 150°F (66°C) shall have an external cover. When external mechanical damage is possible, a cover shall be fabricated to protect the joint and personnel.

6.6 Internal sleeves shall be installed in expansion joints when the fluid velocity of the system, where the expansion joint is to be installed, is greater than the values listed in Section C-3.1 of the EJMA Standards and where the flow velocity exceeds 75% of the velocity calculated using Section C-3.1.4 of the EJMA Standards.

7. Dimensions and Permissible Variations

7.1 Dimensional tolerances on completed expansion joint assemblies shall be in accordance with Section D-2.9 of the EJMA Standards and Standard ES-3 of the Pipe Fabricating Institute.

8. Workmanship, Finish, and Appearance

8.1 The quality of workmanship shall be such as to produce a product that is in accordance with the requirements of this specification and ensures the proper functioning of all parts of the unit.

8.2 The bellows shall be manufactured and carefully handled to prevent surface flaws or deep scratches from being generated. The surface condition of the completed joint assembly shall be free from injurious surface discontinuities and any contaminants that would affect the operation of the assembly.

8.3 On completion of fabrication, and before shipment, the manufacturer shall clean the inside and outside of the completed assembly of all loose scale, grease, dirt, sand, rust, weld spatter, cutting chips, and any other foreign matter by any suitable means. The inside of the assembly shall then be inspected for cleanliness. All openings where practicable shall be suitably closed to prevent the entrance of foreign matter after cleaning and during shipment. The use of chlorinated solvents is prohibited.

9. Inspection

9.1 The responsibility for quality control rests with the manufacturer. However, all phases of fabrication may be subject to review by a representative of the purchaser.

9.2 The inspector representing the purchaser shall have access at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer’s plant that concern the manufacture of the product ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the product is being furnished in accordance with this specification. Inspection shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be scheduled not to interfere unnecessarily with the operations of the manufacturer. This requirement applies to all subcontractors.

9.2.1 Acceptance of a particular phase of manufacturer of an assembly by a purchaser’s representative shall not be considered a waiver of any of the requirements of this specification and shall not relieve the manufacturer of the responsibility of furnishing a satisfactory product.

9.3 When the bellows is formed from a longitudinally butt-welded cylinder, the longitudinal weld(s) shall be 100% liquid penetrant examined on the outside and inside surfaces (if accessible) before forming. Liquid penetrant examination on all accessible inside and outside weld surfaces shall be repeated after forming. All other welds essential to pressure containing or restraining shall be liquid penetrant examined. Ferromagnetic materials may be examined by magnetic particle inspection instead of liquid penetrant at the manufacturer’s option.
10. Rejection and Rehearing

10.1 Expansion joint assemblies or parts thereof indicating fabrication not in accordance with the manufacturing drawings and procedures, or this specification, shall be subject to rejection and shall be resolved in accordance with the manufacturer’s quality assurance program (see Section 14).

10.2 All repairs shall be in accordance with the specified code and other applicable specifications.

10.3 Expansion joint assemblies or parts thereof accepted by the purchaser’s representative at the place of manufacture that subsequently reveal imperfections not previously detected or which by subsequent tests or analysis show nonconformance with this specification are subject to rejection.

11. Certification

11.1 When specified in the purchase order or contract, the manufacturer’s certification shall be furnished to the purchaser. It shall state that each expansion joint has been manufactured, tested, and inspected in accordance with this specification and the requirements have been complied with. When specified, a report of any test results shall be furnished.

11.2 When specified, certification of the conformance to the requirements of this specification may be made by a third party.

11.3 ASTM/ASME mill test reports are required for pressure retaining and containing components.

11.4 No records are required for pipe fittings or flanges provided they are made and marked in accordance with an acceptable standard (such as ANSI). Certificates of conformance are required when the markings are missing or are removed during fabrication.

12. Product Marking

12.1 Each expansion joint shall be provided with a permanently attached corrosion resistant nameplate indicating as a minimum the following information:

12.1.1 Manufacturer’s name.

12.1.2 Manufacturer’s model number.

12.1.3 Design Conditions—pressure, temperature, movements.

12.1.4 This specification number (indicating compliance thereto).

12.1.5 Purchaser’s specified component item number, if ordered.

12.2 When an expansion joint is supplied with an internal liner, a permanent arrow indicating the direction of flow shall be plainly visible on the outside of the expansion joint.

12.3 Impression stamping directly on bellows material is not permitted.

13. Packaging and Shipping

13.1 The expansion joint shall be containerized or shipped on pallets with all materials strapped down and prepared for shipment in such a manner that the quality, cleanliness, and finish shall be maintained during shipment.

13.2 Yellow painted shipping bars shall be furnished to maintain proper shipping length and alignment, and designed not to interfere with the installation of the assembly. The shipping bars shall be removed after installation and before piping system test. Expansion joints with tie rods can be provided with tie rod spacers instead of shipping bars.

13.3 Installation instructions shall be supplied in a weatherproof envelope with each expansion joint assembly.

13.4 When the expansion joint is to be transported to the job site by ship, it should preferably be sent as below deck cargo.

13.5 All external surfaces shall be treated and painted in accordance with the manufacturer’s standard practices, unless otherwise specified. Paint shall be suitable for service temperatures.

14. Quality Assurance

14.1 The manufacturer shall have a current certificate of authorization to manufacture ASME Section VIII, Division 1, Pressure Vessels to assure an adequate quality assurance program that is applicable to all phases of manufacturing, including materials supplied by subcontractors.

14.2 Nothing in this specification shall relieve the manufacturer of the responsibility for performing, in addition to the requirements of this specification, such analyses, tests, inspections, or other activities that the manufacturer considers necessary to ensure that the design, material, and workmanship are satisfactory for the service intended, or as may be required by common usage or good practice.

15. Keywords

15.1 expansion joint; metallic bellows-type expansion joints; piping systems; piping thermal contraction; piping thermal expansion
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are for use when desired by the purchaser. Other requirements not identified in this specification may be included by agreement between the manufacturer and the purchaser.

S1. Documents for Approval and/or Records

S1.1 Manufacturing drawings.
S1.2 Welding procedures and qualifications.
S1.3 Applicable nondestructive examination procedures.
S1.4 Heat treatment procedures or temperature charts, or both.
S1.5 Complete engineering design analysis calculations for the metallic bellows or hardware, or both.
S1.6 ASME partial data forms.

S2. Qualification Testing

S2.1 When specified, the manufacturer shall furnish a first article test assembly to determine conformance with this specification. The test assembly shall consist of the bellows and appropriate end connections. Liners, covers, tie, limit or control rods, hinges, gimbal rings, and other similar devices need not be provided on the first article test unit, unless they are necessary for the performance of the specific test(s) verification.

S2.2 When specified, cyclic endurance testing (fatigue testing) shall be performed for the required number of complete cycles. The test shall be performed under pressure at ambient temperature and the assembly need be cycled in axial movement only.

S2.2.1 During the test, the pressure in the assembly shall be adjusted to simulate, as closely as possible, the maximum design pressure of the unit being qualified. The pressure may vary from this value during each cycle.

S2.2.2 A single test bellows can be used instead of a multiple bellows assembly being qualified.

S2.2.3 In determining the qualifying extension or compression, or both, the equivalent axial movement caused by lateral deflection and angular rotation shall be included. The equivalent axial movement shall be computed in accordance with the EJMA Standards and shall be algebraically added to the specified values of axial movement.

S2.3 The purchaser may require that the expansion joint be certified as passing shock requirements. The shock requirements shall be specified by the purchaser.

S2.3.1 The purchaser may require that the expansion joint be certified as passing vibration requirements. The vibration requirements shall be specified by the purchaser.

S2.3.2 When specified, other qualifying tests shall be performed on a first article test unit under the requirements of the purchaser’s contract.
Standard Specification for International Shore Connections for Marine Fire Applications

1. Scope

1.1 This specification covers the design and manufacture of international shore connections to be used with marine fire fighting systems during an emergency when a stricken ship has a system failure.

1.2 International shore connections are portable universal couplings that permit connection of shipboard firemain systems between one ship and another or between a shore facility and a ship when their respective system threading is mismatched. Both the ship and the facility are expected to have a fitting such that in an emergency can be attached to their respective fire hose and bolted together to permit charging the ship’s system. It must be portable to accommodate hose to hose connection and allow assistance from any position.

1.3 The international shore connection is required by international treaty2,3 to be carried onboard all passenger and cargo vessels of 500 gross tons or more, regardless of firemain size, engaged in international voyages, and is recommended for all vessels that would be expected to render assistance. It is also intended to be provided at shore facilities that would be used to supply water to a ship’s firemain system.

1.4 Fabrication either on board a vessel, in a shipyard, or other shore facility is not precluded by this specification.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Ordering Information

2.1 The purchase order or inquiry for an international shore connection shall include the following as applicable:

2.1.1 Material of construction.
2.1.2 Title, number, and latest revision of this specification.
2.1.3 Maximum operating pressure (psig) (when above 150 psig, see 4.2).
2.1.4 Preservation (coating) requirements (if any, see 7.2).
2.1.5 Diameter and threading to be provided in the coupling.

3. Materials and Manufacture

3.1 The international shore connection may be machined from forgings, castings, plate or bar stock, or may be fabricated out of more than one piece.

3.2 The material shall be brass, bronze, or other suitable corrosion-resistant material. When fabricated out of more than one piece, the flange may be steel and the coupling a corrosion-resistant material. Aluminum shall not be used.

3.3 Nuts, bolts, and washers shall be a corrosion-resistant material.

4. Other Requirements

4.1 Design:

4.1.1 The connection shall consist of a flat face flange and a threaded coupling. Threading shall be specified by the purchaser.

4.1.2 The dimensions of the international shore connection shall be in accordance with Fig. 1.

4.2 The maximum allowable working pressure (MAWP) shall be at least 150 psig (1 N/mm²).

4.3 The international shore connection shall be supplied with four bolts, ¾ in. (16 mm) in diameter, at least 2 in. (50 mm) in length, and threaded at least to within 1 in. (25 mm) of the bolt head.

4.3.1 The bolts shall be supplied with four corresponding nuts and eight washers.

4.4 The international shore connection shall be supplied with a flange gasket suitable for the MAWP and seawater service.

---

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


International Maritime Organization Assembly Resolution A, XII 470, Jan. 4, 1987. This document is available from International Maritime Organization, 4 Albert Embankment, London, U.K. SE1 7SR.
5. Workmanship, Finish, and Appearance

5.1 The quality of workmanship shall be such as to produce a product that is in accordance with the requirements of this specification. Completed units shall be free from imperfections or defects that materially affect appearance or that may affect serviceability.

6. Inspection

6.1 Each finished international shore connection shall be visually examined and dimensionally checked to ensure it corresponds to this specification.

7. Packaging and Preservation

7.1 Unless otherwise specified, the international shore connection shall be packaged for shipment in accordance with the manufacturer's standard commercial practice.

7.2 Preservation of the international shore connection, by the manufacturer or user, shall be satisfactory for preventing deterioration of the connection during long-term storage on vessels or at shore facilities.

8. Quality Assurance

8.1 The manufacturer shall use quality assurance procedures that assure manufacture of high quality international shore connections that are designed in accordance with this specification.

9. Keywords

9.1 fire fighting systems; international shore connections; hose-to-hose connection; marine fire applications; portable universal couplings; shipboard firemain systems; stricken ship

**FIG. 1 International Shore Connection**

NOTE 1—Fire hose coupling may be used.

NOTE 2—For 1½-in. fire hose coupling, the radius will be ¾ in.

NOTE 3—1 in. = 25.4 mm.
Standard Specification for Quick Disconnect Couplings

This standard is issued under the fixed designation F 1122; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the manufacturing data required to produce a variety of styles and sizes of quick disconnect couplings for marine use that ensure interchangeability and safety of operation.

1.2 In general, quick disconnect couplings are hose and pipe end fittings that permit quick mechanical attachment by means other than bolted or threaded fittings. The method of attachment is a male coupling half (adapter) that fits into a female coupling half (coupler) of the same size. By closing attached cam handles, the coupling halves seal, permitting fluids to be transported under pressure through the quick disconnect coupling.

1.3 The values stated in this specification are in inch-pound units with SI units given in parentheses. The values of each system may not be exact equivalents. Therefore, each system should be considered separately.

1.4 The following safety hazards caveat pertains only to the test method described in this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ANSI Standards:
B2.1 Pipe Threads
B16.5 Pipe Flanges and Flanged Fittings, Steel-Nickel Alloy, and Other Special Alloys
B16.24 Bronze Pipe Flanges and Flanged Fittings
B16.42 Ductile Iron Pipe Flanges and Flanged Fittings
B31.1 Power Piping Code

2.2 MSS Standards:
MSS-SP-6 Standard Finish for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings
MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions
MSS-SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)

2.3 ASME Standards:
Section VIII, Division 1, Pressure Vessels
Section IX, Welding and Brazing Qualifications

3. Definitions of Terms Specific to This Standard

3.1 adapter—one half of a quick disconnect coupling that fits into the coupler and seals against an elastomer gasket positioned inside the coupler.

3.2 cam handles—handles that are assembled to the coupler half which by closing engages the adapter sealing the coupling.

3.3 coupler—one half of a quick disconnect coupling that receives the adapter. This half contains the sealing gasket and cam handles (see Fig. 1).

NOTE 1—See Fig. 2 for a description of typical coupler pipe fittings.

4. Classification

4.1 Quick disconnect couplings shall consist of the following types:

4.1.1 Standard Class—This type is to be designed for a 4:1 burst factor of safety.

4.1.2 Class I—This type is to be designed for a 5:1 burst factor of safety.

4.2 Both Standard Class and Class I will be called quick disconnect couplings in the body of this specification unless otherwise specified.

5. Ordering Information

5.1 Purchase orders for quick disconnect couplings under this specification shall include the following applicable information:

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


3 Available from Manufacturers’ Standardization Society of the Valve and Fittings Industry, Inc., 1815 N. Fort Myers Dr., Arlington, VA 22209.

4 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.
5.1.1 Class.
5.1.2 Size and type of each coupling half-end connection.
(Example—2- by 1½-in. NPT).
5.1.3 ASTM material designation and date including alloy specifications for the following:
5.1.3.1 Adapter and coupler halves,
5.1.3.2 Cam handle, and
5.1.3.3 Cam handle pivot pin.
5.1.4 Product or fluid in applicable system.
5.1.5 Shipping instructions.
5.1.6 Any special requirements, such as testing, coatings, and threads.

6. Materials and Manufacture

6.1 Materials:
6.1.1 Pressure-retaining parts shall be manufactured from material specifications and grades listed in Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code or ANSI B31.1.
6.1.2 All other materials of construction shall be of the type specified by the user and shall conform to ASTM, ASME, or Metal Power Industry Federation material specifications. Materials not identified by the ordering data shall be of the manufacturer’s standard and of the same quality used for the intended purpose in commercial practice.
6.1.3 All material incorporated in the work covered by this specification shall be new. The use of rebuilt or used products are not allowed under this specification.
6.1.4 Gaskets are to be produced from a compressible elastomeric material and shall be compatible with the fluid to be transferred (see 5.1.4).

6.2 Manufacture:
6.2.1 Adapters and couplers are to be produced as castings or forgings. Cam handles may be produced by casting, forging, or sintered metal processes. Established commercial processing methods are to be used to produce these parts, provided chemical and physical properties are consistent with those cataloged for the specified materials.
6.2.2 Pipe threads on the service end of couplers or adapters, when specified, shall meet ANSI B2.1.
6.2.3 Flanges on the service end of couplers or adapters, when specified, shall meet ANSI B16.5, B16.24, or B16.42.
6.2.4 Flanges shall be finish machined to specifications shown in MSS-SP-6.
6.2.5 Cam handles assembled to the coupler are to have a safety locking device to ensure against the handles being opened unintentionally or vibrating open. This locking device must require a separate, deliberate effort in the opening operation over the standard handle operation.
6.2.6 Cam handles shall be manufactured to contain the adapter within the coupler under rated pressure with no leakage occurring. The cam action shall not distort the couplers rendering the coupler unusable. The force required to close the cam handles shall be adequate to prevent leakage, but shall be easily attainable through hand operation by an average strength person. Handles should not need to be hammered closed.
6.2.7 Welding procedure qualifications, welder performance qualifications, and welding materials shall be in accordance with ANSI B 31.1 and Section IX of the ASME Code. Brazing or soldering shall not be used. Where radiography is required (see 12.1), all welds shall be butt welds.

7. Other Requirements

7.1 All couplings shall have a maximum allowable working pressure of not less than 150 psi (1034 kPa).

7.2 Maximum allowable working pressure (MAWP) for a Standard Class coupling shall be 25% of its burst pressure.

7.3 Maximum allowable working pressure for a Class I coupling shall be 20% of its burst pressure.

7.4 Burst pressure shall be determined in accordance with Section VIII, Division 1 of the ASME Code.

8. Dimensions

8.1 The dimensions and tolerances required to ensure interchangeability of adapter and coupler halves, of common sizes, shall be as given in Figs. 3-15.

8.2 Sizes as listed in the tables correspond to NPS for piping systems.

9. Workmanship, Finish, and Appearance

9.1 Couplings are to be produced with quality workmanship. Casting surface quality is to be in accordance with MSS-SP-55. Machined surfaces are to be finish machined to a 125-µin. (3175-µmm) (AA) finish or better with no porosity showing.

9.1.1 Couplings are to be free of burrs or sharp edges. Machined surfaces are to be free of nicks or scratches that may affect the sealing capabilities of the couplings.

9.1.2 Surfaces are to be sound with good appearance and true pattern. Internal surfaces, if not machined, shall be smooth, as expected from good quality casting, and free from any flaw that would render the part unsafe for its intended use.

9.2 Cam handles are to be smooth, having no burrs or sharp edges. Cam closing surface is to be continuous, providing an increasing axial pull on mating adapter until proper seating against the gasket occurs.

9.3 Defective parts are not to be repaired by welding, brazing, or any other method, to fill porosity or other flaws in the casting.

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**TABLE 3**

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**FIG. 3** Adapter End Dimensions
9.4 Gaskets are to be produced having parallel sealing faces. Faces are not to contain any imperfections that will allow leakage to occur at working pressure.

10. Number of Tests

10.1 A prototype coupling of each size of each particular design shall be tested to determine conformance to this specification.

10.2 Each coupling shall be tested as outlined in production testing of 11.2.

11. Test Methods

11.1 Prototype testing of each size of each particular design shall be as follows. Maintain the indicated test pressures for at least 1 min without leakage.

11.1.1 Pressure test to twice the MAWP after having been cycled (connected, closed, opened, and disconnected) three times.

11.1.2 Pressure test at MAWP while applying a moment of 1000 in.-lbs (113 N·M) to one coupling half attempting to twist it loose. Reapply MAWP after the moment is removed.

11.2 Production Test—Hydrostatically test each coupling to 1.5 times MAWP.

11.3 The test apparatus for 11.2 is to be a state-of-the-art device, designed to apply internal pressure to the coupling halves with gasket in place. Dye the fluid used to apply the hydrostatic pressure to facilitate observation of leakage should leakage occur.

12. Inspection

12.1 Nondestructive examination of welds shall be performed as required by ANSI B31.1. Additionally, 100 % radiography of all welds is required for couplings equal to or greater than 4-in. (100-mm) nominal diameter and when the nominal wall thickness is greater than 0.375 in. (9.4 mm). The manufacturer is responsible for the inspection and testing of each coupling and assuring conformity to this specification. Samples selected for inspection, at least one coupling from each lot of 100 or fraction thereof, are to be dimensionally checked 100 % to verify adherence to this specification. Couplings having threads are to be inspected using proper thread gages. The entire lot of couplings is to be

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Note 1—Unidentified tolerances; fractional = ± 1/64 (± 0.4), angular = ± 2° (± 0.035 rad), decimal = ± 0.005 (± 0.127)

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FIG. 4 Coupler End Dimensions
visually checked for porosity and other flaws that could adversely affect usability of this product.

12.3 The manufacturer shall afford the purchaser’s inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer’s operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

12.4 Other tests, when agreed upon, shall be made from material of the lots covered in the order.

13. Certification

13.1 When specified in the purchase order or contract, the manufacturer’s certification shall be furnished to the purchaser stating that the samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When
specified in the purchase order or contract, a report of the test
results shall be furnished.

14. Product Marking

14.1 Each adapter and coupler shall be marked in accor-
dance with MSS-SP-25 including the following:
14.1.1 ASTM designation of this specification.
14.1.2 “Cl I” if it is a Class I adapter or coupler.

15. Packaging and Package Marking

15.1 The couplings shall be packed according to the manu-
facturer’s standard practice, providing reasonable care to
prevent lost or damaged parts in shipment.

15.2 Containers and packages shall be marked or tagged to
adequately identify the contents or purchaser’s order number.

16. Quality Assurance

16.1 The manufacturer of the quick disconnect couplings
shall maintain the quality of the couplings that are designed,
tested, and marked in accordance with this specification. At no
time shall a coupling be sold with this specification designation
that does not meet the requirements herein.

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FIG. 6 Coupler Female Thread End
**Note 1**—A chain boss and number of flats or lugs provided is at the manufacturer’s discretion. Unidentified tolerance; fractional ±\(\frac{3}{64}\) (±0.8)

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**FIG. 7 Adapter Male Thread End**
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FIG. 8 Coupler Male Thread End
**NOTE 1**—A chain boss provided at the manufacturer’s discretion.

**NOTE 2**—Additional barbs may be provided at the manufacturer’s discretion.

Unidentified tolerances = ± 1/32 (±0.8)

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<td>135</td>
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<td>28.6</td>
<td>68.3</td>
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<td>2</td>
<td>102.4</td>
<td>100</td>
<td>5</td>
<td>160</td>
<td>9.5</td>
<td>28.6</td>
<td>68.3</td>
<td>11.1</td>
</tr>
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<td>116</td>
<td>5</td>
<td>183</td>
<td>9.5</td>
<td>28.6</td>
<td>68.3</td>
<td>11.1</td>
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<td>3</td>
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<td>131</td>
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<td>206</td>
<td>9.5</td>
<td>28.6</td>
<td>68.3</td>
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<td>5</td>
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<td>164</td>
<td>6</td>
<td>253</td>
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<td>68.3</td>
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<td>180</td>
<td>6</td>
<td>277</td>
<td>9.5</td>
<td>28.6</td>
<td>68.3</td>
<td>11.1</td>
</tr>
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</table>

FIG. 9 Hose Shank End
### FIG. 10 Flanged Coupler ANSI Class 150

<table>
<thead>
<tr>
<th>Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>19/32</td>
<td>2 9/16</td>
<td>3/32</td>
</tr>
<tr>
<td>⅝</td>
<td>19/32</td>
<td>2 9/16</td>
<td>3/32</td>
</tr>
<tr>
<td>7/8</td>
<td>19/32</td>
<td>2 9/16</td>
<td>3/32</td>
</tr>
<tr>
<td>1</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
</tr>
<tr>
<td>1 ¼</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
</tr>
<tr>
<td>1 ½</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
</tr>
<tr>
<td>2</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
</tr>
<tr>
<td>2 ½</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
</tr>
<tr>
<td>3</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
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<tr>
<td>4</td>
<td>7/32</td>
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<tr>
<td>6</td>
<td>7/32</td>
<td>2 7/8</td>
<td>7/32</td>
</tr>
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</table>

### FIG. 11 Flanged Adapter ANSI Class 150

<table>
<thead>
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<th>A</th>
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<th>C</th>
</tr>
</thead>
<tbody>
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<tr>
<td>6</td>
<td>15/32</td>
<td>1 ¼</td>
<td>3/32</td>
</tr>
</tbody>
</table>

Note 1—Chain boss to be provided at the manufacturer's discretion.
### FIG. 12 Adapter Chain Boss End

### FIG. 13 Gasket

#### Table 1

<table>
<thead>
<tr>
<th>Size</th>
<th>Dimensions, in. (mm)</th>
<th>Minimum Gasket Compression for Proper Sealing</th>
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<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1/2</td>
<td>(2.4)</td>
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<td>(0.64)</td>
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<td>(1)</td>
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<td>2</td>
<td>(3)</td>
<td>(1)</td>
</tr>
<tr>
<td>2 1/2</td>
<td>(4)</td>
<td>(1)</td>
</tr>
<tr>
<td>3</td>
<td>(4)</td>
<td>(1)</td>
</tr>
<tr>
<td>4</td>
<td>(5.6)</td>
<td>(1.4)</td>
</tr>
<tr>
<td>5</td>
<td>(5.6)</td>
<td>(1.4)</td>
</tr>
<tr>
<td>6</td>
<td>(5.6)</td>
<td>(1.4)</td>
</tr>
</tbody>
</table>

#### Note 1

Unidentified Tolerance; Fractional = ±1/64 (±0.4)
### FIG. 14 Cam Handle

**Note 1**—Unidentified tolerance: fractional ± 1/64 (± 0.4)

<table>
<thead>
<tr>
<th>Size (in.)</th>
<th>Dimensions, in. (mm)</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
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<td>5/32</td>
<td>4</td>
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<td>5/32</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>1 7/8 (47.6)</td>
<td>5/32</td>
<td>4</td>
</tr>
<tr>
<td>1 1/4</td>
<td>1 7/8 (47.6)</td>
<td>5/32</td>
<td>4</td>
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<tr>
<td>1 1/2</td>
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<td>4</td>
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<td>2</td>
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<td>5/32</td>
<td>4</td>
</tr>
<tr>
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<td>3 (76.2)</td>
<td>5/32</td>
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<td>3 (76.2)</td>
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<td>4</td>
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<tr>
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<td>3 (76.2)</td>
<td>5/32</td>
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<td>3 (76.2)</td>
<td>5/32</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>3 (76.2)</td>
<td>5/32</td>
<td>4</td>
</tr>
</tbody>
</table>

### FIG. 15 Pull Ring, Cam Handle

**Note 1**—Unidentified tolerance: ± 3/32 (± 1.6); decimal ± 0.002 (± 0.05)

<table>
<thead>
<tr>
<th>Size (in.)</th>
<th>Dimensions, in. (mm)</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>3/32</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3/16</td>
<td>3/32</td>
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<td>1/4</td>
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</tr>
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<td>4</td>
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</tbody>
</table>
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Standard Specification for Non-Metallic Expansion Joints

1. Scope

1.1 This specification provides the minimum requirements for construction, materials, performance, and dimensional requirements of arch-type non-metallic expansion joints.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test method described in this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
D 1418 Practice for Rubber and Rubber Latices—Nomenclature

2.2 Federal Standard:
Code of Federal Regulations, Title 30, Chapter I, Mine Safety and Health Administration

2.3 ANSI Standards:
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.24 Bronze Flanges and Flanged Fittings

3. Terminology

3.1 Definitions:
3.1.1 floating metallic flange type—expansion joint having the tube, fabric plies, and cover brought up from the joint body to form a bead.

4. Ordering Information

4.1 Orders for products under this specification shall include the following information:

4.1.1 Inside diameter of connecting pipes (joint ID).
4.1.2 Face-to-face dimension that is the flange-to-flange dimension into which the expansion joint is to be installed.
4.1.3 Maximum and minimum operating pressure in pounds-force per square inch gage (pascals).
4.1.4 Maximum and minimum operating temperature in °F (°C).
4.1.5 Fluid to be handled.
4.1.6 This ASTM specification designation.
4.1.7 Movement data requirements (including shock or vibratory excursions if applicable).
4.1.8 Design certification burst test if required (see 9.1).
4.1.9 Hydrostatic or special tests if required (see 9.2).

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


2 Annual Book of ASTM Standards, Vol 01.02.
3 Annual Book of ASTM Standards, Vol 09.01.
5 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

4.1.11 Certification of expansion joint if required (see Section 12).
4.1.12 Certified detailed drawing of the expansion joint if required (see 12.2).

5. Materials and Manufacture

5.1 Expansion joints shall be fabricated with an elastomeric tube reinforced with multiple plies of woven cloth or tire cord covered with synthetic rubber. The inner tube shall be a natural rubber, synthetic rubber, or blend of synthetic rubber that meets the requirements of this specification. The woven cloth or tire cord shall be nylon, polyester, fiberglass, or aramid. Cotton is not acceptable. The reinforcing fabric shall be impregnated with a compatible friction stock. Additional reinforcement to the fabric may be provided in the body of the expansion joint and may be solid metal rings or wire imbedded in the synthetic rubber. Tensile properties of the wire, if used, shall be as given in 5.2. Body rings, if used, must be welded before being installed in the expansion joint body. Welds must be 100% penetration.

5.1.1 The list of elastomers used in expansion joints and rubber pipe in accordance with the Technical Handbook lists acceptable natural rubber and synthetic elastomers for construction of non-metallic expansion joints.

5.2 Reinforcing wire shall have properties that allow the expansion joints to meet the requirements of this specification.

5.3 All expansion joints shall be manufactured with a cover of Hypalon or Neoprene (Chloroprene), in accordance with Practice D 1418. This cover material must consist of 100% Hypalon or Chloroprene (not blended with any other elastomer) plus normal additives to provide for curing and a durometer between 50 and 75 on the Shore A Scale. Neoprene and Hypalon are selected as the best fire-retardant elastomer of the common types used for expansion joints. This material shall be certified flame resistant as outlined in 10.3.

5.4 Integral Flanges—The tube, fabric plies, and cover shall be brought up from the joint body to form an integral flange. This rubber flange shall extend beyond the bolt holes of the retaining ring.

5.5 Floating Metallic Flanges—The metal flanges shall have a groove to accept the molded bead in the body at each end of the expansion joint bellows.

5.6 Arches—Arches may be either straight sided or long radius depending on the manufacturer’s standard construction. The arch size and shape determine the movement capability of the joint. Minimum movement capability of single arch joints shall be in accordance with the Technical Handbook table titled “Expansion Joint Movement Force/Spring Rate Capability.” Movement capability information for multiple arch joints shall be available from the manufacturer.

5.7 Metallic Flanges:

5.7.1 Flanges shall be drilled in accordance with the Technical Handbook appendix titled “Common Flange Dimension/Drilling Chart” or in accordance with the customer order as required, to match the mating flanges.

5.7.2 Metallic flanges shall meet the material requirements and pressure-temperature ratings in accordance with ANSI B16.1, B16.5, or B16.24.

5.8 Retaining Rings—Retaining rings for the integral flange type are installed behind the flanges and are drilled to match the flange drilling. The sections supplied for each flange should be split at the bolt holes to ensure a proper seal at all points when the bolts are tightened. The edge next to the rubber flange shall be broken or bevelled to prevent cutting the rubber flanges. Retaining rings must be a minimum thickness of \( \frac{3}{8} \) in. (9.5 mm) and shall be made of steel or ductile iron. Carbon steel shall be in accordance with Specification A 395.

6. Other Requirements

6.1 All expansion joints shall be designed for a minimum burst pressure of four times the maximum allowable working pressure. The design shall be based on analytical or experimental test of expansion joints of similar construction, class, type, and size. The design shall be certified by tests if ordered (see 4.1.9).

6.2 Performance Requirements—Single arch expansion joint movement shall not exceed the limits of the Technical Handbook table referred to in 5.6 unless the manufacturer certifies that a proposed design can exceed the listed minimum movement capability to meet a special requirement greater than the minimum listed. Multiple arch-joint movement shall be of the manufacturer’s certified design.

6.3 Pressure Rating—Expansion joints shall be limited to the pressures listed in the table “Pressure Characteristics of Rubber Expansion Joints” of the Technical Handbook.

7. Dimensions and Permissible Variations

7.1 Expansion joints shall be dimensioned in accordance with the Technical Handbook table titled “Expansion Joint Movement/Force/Spring Rate Capability.”

8. Workmanship, Finish, and Appearance

8.1 Tube—The tube shall be free from cuts and breaks or severe abrasions. Small depressions and indentations are acceptable as long as the surface of the elastomer is not broken.

8.2 Integral Rubber and Fabric Flange:

8.2.1 The face of an integral rubber and fabric flange shall be free of cuts or obvious breaks and shall be covered with rubber. The most critical portion of the flange is from the inside diameter of the joint out to the bolt holes.

8.2.2 Bolt holes shall be drilled cleanly through the rubber flange. The retaining rings shall be checked for proper alignment with bolt holes.

8.2.3 The outer edge of the flange shall be sealed with rubber, so that moisture from the atmosphere cannot attack the reinforcing fabrics.

8.2.4 The surface of the rubber flange against which the retaining rings are installed shall be covered with rubber. The surface may be irregular and building form tooling marks are not objectionable.

8.3 Expansion Joint Cover and Body—The cover of a joint does not contribute to the strength of the joint. Its purpose is to keep fluids from the atmosphere or surroundings from being absorbed into the body plies of fabric. Surface blemishes, such as flash, nylon wrap markings, grooves, and other indentations...
in the cover, over the arch, or in the body area, are not harmful as long as the body fabric is not exposed.

9. Number and Type of Tests

9.1 Prototype Test:

9.1.1 When required by the purchaser, an expansion joint of each size and type shall be burst tested to determine its maximum allowable working pressure (see 10.1).

9.1.2 The outer covering material of the expansion joint shall be tested to determine its self-extinguishing characteristics (see 10.3).

9.2 Production Test—When required by the purchaser, an expansion joint shall be hydrostatically tested to 1.5 times its maximum allowable working pressure at its rated maximum operating temperature (see 10.2).

10. Test Methods

10.1 Burst Test—Fill each joint to be tested with water before the application of pressure, allowing all air in the joint to escape. Apply pressure at a uniform rate until failure of the joint occurs. Consider the pressure at which any fluid leakage first occurs as the bursting pressure of the joint. The maximum allowable working pressure of the joint shall be less than or equal to \( \frac{1}{4} \) the bursting pressure determined by this test.

10.2 Hydrostatic Test—Fill each joint to be tested with water before the application of pressure, allowing all air in the joint to escape. Apply pressure at a uniform rate up to the test pressure. The joint shall show no sign of leakage at the test pressure.

10.3 Flame Resistance Test—Test four specimens of the joint, \( \frac{1}{2} \) by 6 in. (12.7 by 152.4 mm) by the thickness of the expansion joint, in accordance with 30 CFR 18.65(b) through (d). Consider the expansion joint flame resistant if the tests of the four specimens meet the test requirements in 30 CFR 18.65(e).

11. Inspection

11.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

12. Certification

12.1 When specified in the purchase order or contract, the manufacturer’s certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12.2 When specified in the purchase order or contract, a certified drawing detailing the expansion joint shall be provided.

13. Product Marking

13.1 Each expansion joint shall be permanently marked or tagged with the following information:

13.1.1 Manufacturer’s name or trademark.

13.1.2 Nominal diameter.

13.1.3 Manufactured date (month and year).

13.1.4 Maximum allowable working pressure and temperature (psi/°F (Pa/°C)).

13.1.5 Face-to-face dimension.

13.1.6 ASTM designation and year of issue of this specification.

14. Quality Assurance

14.1 The manufacturer of the expansion joint shall maintain the quality of the joints that are designed, tested, and marked in accordance with this specification. At no time shall a joint be sold with this specification designation that does not meet the requirements herein.

15. Keywords

15.1 arch-type non-metallic expansion joints; expansion joints
1. Scope

1.1 This practice describes a standard procedure for inspecting the coating system of a ship’s topside and superstructure, tanks and voids, decks and deck machinery, and underwater hull and boottop during drydocking. Included are a standard inspection form to be used for reporting the inspection data, a diagram that divides topside and superstructure individual inspection areas, and a series of diagrams that are used to report the extent of damage to the coating system.

1.2 This practice is intended for use only by an experienced marine coating inspector.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints
D 714 Method for Evaluating Degree of Blistering of Paints
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints

2.2 Steel Structures Painting Council:
SSPC-PA-2 Measurement of Dry Paint Thickness With Magnetic Gages

3. Significance and Use

3.1 This practice establishes the procedure for the inspection of coating systems on board ships. It contains a series of diagrams to be used to report the extent of damage to coatings.

4. Reference Standards

4.1 Extent of Failure—The overall extent of failure diagrams (see Fig. 1) and the extent within affected area diagrams (see Fig. 2 and Fig. 3) are used to report the area covered by various fouling organisms, different types of corrosion, and paint failures. The overall extent of failure diagrams are used first to group all areas where a particular type of damage has occurred into one contiguous block. The extent within affected area diagrams are then used to identify the pattern of damage within that contiguous block. (For example, inspection for Section I.A.—General Corrosion (see Figs. 4-7) and general corrosion appears distributed over the entire inspection area as shown by the black areas in Fig. 8.)

4.1.1 The first step is to draw an imaginary line that would enclose all of the general corrosion. This enclosure should be as small as possible. Select the diagram from the overall extent of failure diagrams that most closely approximates the enclosed area with respect to the entire inspection area. Using the general corrosion example, the enclosed area (shaded area) would closely match Fig. 9.

4.1.2 Enter a “6” (for Diagram 6 in Fig. 1) in the box next to I.A.1. overall extent of failures in Fig. 4.

4.1.3 The second step is to look at only the enclosed area and select the diagram from the extent within affected-area diagrams that most closely identifies the pattern of general corrosion in the enclosed area. In this example, Fig. 10 (Diagram N) would be a good choice.

4.1.4 Enter an “N” (for Diagram N in Fig. 3) in the box next to I.A.1.A. extent within the affected area.

Note 1—Selection of diagrams is based on visual comparisons, and therefore, different inspectors may select different diagrams. The diagrams are designed to minimize these differences and enhance reproducibility.

4.2 Forms of Mechanical Damage—This reference standard (Fig. 11) is a series of photographs used to identify the various forms of mechanical damage to a coating that can lead to corrosion.

4.3 Types of Corrosion—This reference standard (Fig. 12) is a series of photographs used to show examples of general coating damage. Included could be general corrosion, pitting corrosion, pin-point corrosion, galvanic corrosion/coating undercutting, cavitation corrosion, corrosion along welds, and rust staining.

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2 Available from ASTM Annual Book of ASTM Standards, Vol 06.01.

3 Available from Steel Structures Painting Council, 40 24th St., Pittsburgh, PA 15222-4656.
4.4 Levels of Delamination—This reference standard (Fig. 13) is a series of diagrams that identifies the levels in a coating system where delamination can occur.

5. Requirements for Inspectors

5.1 The inspector must be able to perform the following tasks:
5.1.1 Calibrate and use a magnetic gage to measure dry film thickness (DFT).
5.1.2 Use pH paper or pH meter properly.
5.1.3 Use a camera properly.
5.1.4 Recognize the various types of corrosion and forms of paint failures (blistering, delamination, etc.).
5.1.5 Recognize the various ship areas as described in Figs. 14-16.

6. Procedure

6.1 The inspection form consists of two pages to be completed by the inspector and four pages of reference standards. Complete the first of the two pages as shown in Fig. 17. This form, which is self-explanatory, requests general information about the ship.

6.2 The second page of the applicable inspection form to be completed by the inspector is shown in Figs. 4-7. Complete a separate inspection form for each of the inspection areas delineated in Figs. 14-16. Instructions for completing the form (shown in Figs. 4-7) are given in Section 7.

6.2.1 For the ship’s topside and superstructure, divide the inspection area into six sections. These six inspection areas are defined by the diagram in Fig. 14. For each complete inspection, complete one form, shown in Fig. 4, for each section.

6.2.2 For the ship’s tanks and voids, divide the inspection area into seven sections. These seven inspection areas are defined by the diagram in Fig. 15. For each complete tank inspection, complete one form, shown in Fig. 5, for each section.

6.2.3 For the ship’s underwater hull and boottop, divide the inspection area into twelve inspection areas. These twelve inspection areas are defined by the diagram in Fig. 16. For each complete underwater hull inspection, complete one form, shown in Fig. 6, for each section.

6.2.4 For the ship’s deck and machinery, the inspection area is a code which is used to designate an area of the ship’s deck.
or a piece of deck machinery. The purpose of the code is to identify positively the area being inspected so that a history of inspection data can be gathered. For sections of the ship other than decks and deck machinery (that is, underwater hull, boottop, topside, superstructure, tanks, and voids), it is possible to develop a general diagram with logical inspection areas and inspection area codes. Decks and deck machinery vary so greatly between ship types that the development of a general diagram with logical inspection areas and inspection area codes is not feasible. It should be the responsibility of the organization that authorizes the inspections to develop the ship diagram, logical inspection areas, and inspection area codes and to make certain that this same coding system is used during all subsequent inspections.

7. Form Instructions

7.1 Inspection Area—The topside/superstructure is divided into six inspection areas (see Fig. 14). Enter the code for the area being inspected. (For example, enter “SA” for the superstructure aft; “SM” for the superstructure midships; “SF” for the superstructure forward; “SO” for other superstructure, that is, bulwarks, vents, sideport openings, etc.; “HS” for hull starboard; and “HP” for hull port.)

7.1.1 A tank is segmented into seven inspection areas (see Fig. 15. Enter the code for the area being inspected. (For example, enter “B” for the bottom of tank inspection, “A” for the aft bulkhead, etc.) A complete list of tank segments and their codes is shown in Fig. 15.

7.1.2 The underwater hull and boottop are segmented into twelve distinct inspection areas. Enter the code for the area being inspected. (For example, enter “P1” for the port bow inspection, “S1” for the starboard bow inspection, etc.) A complete list of hull segments and their codes is shown in Fig. 16.

7.1.3 Decks and deck machinery vary so greatly between ship types that the development of a general diagram with logical inspection areas and inspection area codes is not feasible. It should be the responsibility of the organization that authorizes the inspections to develop the ship diagram, logical inspection areas, and inspection area codes and to make certain that this same coding system is used during all subsequent inspections.

7.2 Date—Enter the date of the inspection. If the inspection requires more than one day, enter the date the inspection is completed.

7.3 Ship Name—Enter the ship’s name (for example, LPH-14, USS Trenton).

7.4 Hull Number—Enter the builder’s hull number of the ship (for example, Nassco No. 1182).

7.5 Inspector’s Name—The inspector should print his name.

7.6 Tank Number—Enter tank designation.

7.7 Tank Type—Enter type (for example, fuel oil, ballast, etc.).

7.8 Required Photographs—For each inspection area, a photograph of the entire area is required. If the area is too large to capture in one photograph, the area should be divided into equal-sized segments and each segment should be photographed. An individual close-up photograph of each damaged section in the inspection area is required. Each photograph should be marked with the area number, ship name, and date. Also a size scale should be captured in each photograph. This size scale is a reference standard that would be used to determine the approximate size of the photographed ship area. (For example, a 12-in. (304.8-mm) rule might be an appropriate size scale for a relatively small ship area.)

7.9 Inspection Area Obscured—If the inspection area is completely obscured and cannot be inspected, circle the “Y.” This condition of being completely obscured will probably occur most frequently in the bottom inspection area (“B”) where dirt and other contaminants have settled. If the inspection area is not completely obscured, circle the “N.”

8. Classification of Corrosion

8.1 The inspector should distinguish between six types of corrosion and report each type separately. The six types of corrosion are as follows:

8.1.1 General Corrosion—General corrosion, for the purposes of this inspection form, is all corrosion that is not covered in the mechanical damage, pitting corrosion, pinpoint
corrosion, galvanic corrosion/coating undercutting, or rust staining in 8.1.2, 8.1.3, 8.1.4, 8.1.5, and 8.1.6. Patches of common, ordinary rusting are classified as general corrosion.

8.1.2 Mechanical Damage—Mechanical damage corrosion is corrosion that occurred because the paint was removed from the hull by some type of scraping or impact against the hull. With the paint removed and the steel hull exposed to sea water, corrosion occurred. Photographic examples of corrosion caused by various forms of mechanical damage (that is, scraping/impact, anchor chains/ropes, and internal welds/burning) are shown in Fig. 8.

8.1.3 Pitting Corrosion—Pitting corrosion is a more advanced form of localized corrosion. Pitting corrosion is characterized by visible indentations or pits that have penetrated
into the steel hull surface. These pits distinguish between pitting corrosion and general corrosion, the latter being characterized by a layer of rust that does not penetrate locally into
Fig. 6 Underwater Hull and Boottop

<table>
<thead>
<tr>
<th>Inspection Area</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship Name</td>
<td></td>
</tr>
<tr>
<td>Hull Number</td>
<td></td>
</tr>
<tr>
<td>Inspector's Name</td>
<td></td>
</tr>
</tbody>
</table>

**Required Photographs**
1. Entire Area
2. Close-Up of All Damage

**Fouling**
- A. Slime
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- B. Grime
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- C. Barnacles
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- D. Tubeworms
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- E. Other
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- F. Corrosion/Paint Failures Obscured by Fouling? Y N
- G. Pitting Under Fouling? Y N

**Corrosion**
- A. General
  1. Overall Extent of Failure
- B. Mechanical Damage
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
  2. Type of Damage
     - A. Grounding
     - B. Scratching/Impact
     - C. Anchor Chains/Ropes
     - D. Internal Welds/Burning
     - E. Damage from Scrubbing
- C. Pitting Corrosion
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- D. Pick-Paint Corrosion
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- E. Caviation (PS, SS, A Only)? Y N
- F. Galvanic Corrosion/Coating Undercutting? Y N

**Paint Condition**
- A. Delamination
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
  2. Topcoat
  3. Within Repair System
  4. Between Original/Repair
  5. Within Original System
  6. To Primer Coat
- B. Blistering (Test Method D 714)
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
  2. Size (Test Method D 714)
  3. Density (Test Method D 714)
  4. % Broken Blister
  5. Organic Odor in Blister? Y N
  6. Blister Contains Water? Y N
  7. Corrosion Under Blister? Y N
- C. Cracking
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- D. Checking (Test Method D 550)
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
- E. Flaking (Test Method D 772)
  1. Overall Extent of Failure
     - A. Extent Within Affected Area
  2. Severity
     - F. Sags or Curtains? Y N
     - G. Erosion? Y N
- H. Knife Test
  1. Acceptable? Y N
     - If "N," Mark Level(s) Below
     - A. Topcoat
     - B. Within Repair System
     - C. Between Original/Repair
     - D. Within Original System
     - E. To Primer Coat
     - F. To Steel Substrate

**IV. Measured Properties**
- A. Dry Film Thickness (mil) (SSPC-PA-2)
<table>
<thead>
<tr>
<th>Spot 1</th>
<th>Spot 2</th>
<th>Spot 3</th>
<th>Spot 4</th>
<th>Spot 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

  1. More DFT Readings? Y N

**V. Dielectric Shields**
- A. Blistering? Y N Y N
- B. Delamination? Y N Y N
- C. Fouling? Y N Y N
- D. Corrosion
  1. General? Y N Y N
  2. Pitting? Y N Y N
- E. Film Thickness (mil) Y N
- F. Calcareous Deposit? Y N
- G. Erosion? Y N

**VI. Recommendations**

Copy to Ship's Officer Y N

Acknowledged Receipt Y N

FIG. 6 Underwater Hull and Boottop
the surface but is more uniform in extent. A photographic example of pitting corrosion is shown in Fig. 12.

8.1.4 Pin-Point Corrosion—Pin-point corrosion is characterized by a pattern of small spots (pin-points) of rust. A photographic example of pin-point corrosion is shown in Fig. 12.

8.1.5 Galvanic Corrosion/Coating Undercutting—Galvanic corrosion is characterized by the rapid deterioration of one metal at or near a bimetallic joint. Galvanic corrosion some
times results in coating removal or undercutting. A photographic example is shown in Fig. 12.

8.1.6 Rust Staining—Rust staining occurs on top of the coating with no penetration to the substrate. A photographic example is shown in Fig. 12.

9. Examination of Fouling (Underwater Hull and Boottop)

9.1 Slime:

9.1.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of slime fouling. If there is no slime fouling in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

9.1.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of slime fouling within the affected area. If the overall extent of failure box as specified in 9.1.1 is marked with a “0” (zero), leave the extent within affected area box blank.

9.2 Grass:

9.2.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of grass fouling. If there is no grass fouling in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

9.2.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of grass fouling within the affected area. If the overall extent of failure box as specified in 9.2.1 is marked with a “0” (zero), leave the extent within affected area box blank.

9.3 Barnacles:
9.3.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of barnacle fouling. If there is no barnacle fouling in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

9.3.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of barnacle fouling within the affected area. If the overall extent of failure box as specified in 9.3.1 is marked with a “0” (zero), leave the extent within affected area box blank.

9.4 Tubeworms:
9.4.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of tubeworm fouling. If there is no tubeworm fouling in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

9.4.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of tubeworm fouling within the affected area. If the overall extent of failure box as specified in 9.4.1 is marked with a “0” (zero), leave the extent within affected area box blank.

9.5 Other:
9.5.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instruction for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of fouling other than slime, grass, barnacles, or tubeworm fouling. If there is no fouling other than slime, grass, barnacles, or tubeworms in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.
on Fig. 6. If the metal substrate is relatively smooth and free of indentations and pit corrosion, circle the “N.”

10. Examination of Corrosion

10.1 General:

10.1.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of general corrosion. If there is no general corrosion in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

10.1.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of general corrosion within the affected area. If the overall extent of failure box as specified in 10.1.1 is marked with a “0” (zero), leave the extent within affected area box blank.

10.2 Mechanical Damage:

10.2.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of corrosion caused by mechanical damage. If there is no corrosion caused by mechanical damage in this inspection area, enter the number “0” (zero) and leave the next box (extent within affected area) blank.

10.2.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of corrosion as a result of mechanical damage within the affected area. If the overall extent of failure box as specified in 10.2.1 is marked with a “0” (zero), leave the extent within affected area box blank.

10.2.3 Type of Damage—If corrosion caused by mechanical damage has occurred, use the photographic examples in Fig. 11 to identify the type of mechanical damage that has occurred. On the inspection form, mark an “X” in the box next to the type of damage (that is, scraping/impact, internal welds/burning, anchor chains/ropes/cables) that has occurred.

10.3 Pitting Corrosion:

10.3.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of pitting corrosion. If there is no pitting corrosion in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

10.3.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of pitting corrosion within the affected area. If the overall extent of failure box as specified in 10.3.1 is marked with a “0” (zero), leave the extent within affected area box blank.

10.4 Pin-Point Corrosion:

10.4.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1),
enter the number of the diagram that most closely approximates the overall extent of pin-point corrosion. If there is no pin-point corrosion in this inspection area, enter the number “0” (zero), and leave the next box (extent within affected area) blank.

10.4.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of pin-point corrosion within the affected area. If the overall extent of failure box above is marked with a “0” (zero), leave the extent within affected area box blank.

10.5 Galvanic Corrosion/Coating Undercutting—Galvanic corrosion/coating undercutting occurs most frequently in situations in which dissimilar metals are joined (that is, near posts, mounts, bolts, and especially when an aluminum superstructure is mounted on a steel hull). Galvanic corrosion/coating undercutting is characterized by corrosion that may begin beneath undamaged coating. The corrosion undercutts and lifts the coating as it progresses. If galvanic corrosion/coating undercutting is present, the inspector should circle the “Y.” Otherwise the “N” should be circled.

10.6 Rust Staining—Rust staining is a brownish, rust-colored discoloration that occurs when loose rust particles are carried by water across a painted surface and are absorbed into the paint giving a brownish stain. It is important to distinguish between rust staining that is simply a discoloration and corrosion that is a paint failure. If rust staining has occurred in the inspection area, circle the “Y.” If no rust staining has occurred, circle the “N.”

10.7 Corrosion Along Welds—Corrosion is prevalent along the welds in tanks and voids. Check all welds and circle “Y” if any weld or any area immediately adjacent to a weld is corroded. If all welds and adjacent areas are free of corrosion, circle the “N.”

10.8 Cavitation (P5, S5, A Only)—If you are not inspecting the P5 (port stern), S5 (starboard stern), or A (appendages—struts, rudder, etc.) inspection area, disregard this section. If you are inspecting the P5, S5, or A area, use the photographic example in Fig. 12 to determine if cavitation has occurred. If cavitation has occurred circle the “Y” next to P5, S5, A only. If cavitation has not occurred, circle the “N.”

PAINT CONDITION

11. Examination of Paint Conditions

11.1 Delamination—Delamination is characterized by detachment of the coating from the substrate or by a layer separation between the coats of paint.

11.1.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of delamination. If there is no delamination in this inspection area, enter the number “0” and proceed to 11.2.

11.1.2 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of delamination within the affected area. If the
overall extent of failure box as specified in 11.1.1 is marked with a "0" (zero), leave the extent within affected area box blank.

11.1.3 Topcoat—Mark an “X” in the box beside topcoat if topcoat delamination has occurred. Topcoat delamination has occurred if only the outermost coating has separated from all undercoats. A diagram of topcoat delamination is shown in Fig. 13.

11.1.4 Within Repair System—Mark an “X” in the box beside within repair system if delamination has occurred between layers of the repair system excluding delamination between the topcoat and the outermost undercoat. (This is topcoat delamination.) The repair system is defined as any coating system that is applied on top of the original coating system. If the original coating system has not been overcoated, delamination within the repair system is not possible. A diagram of delamination within the repair system is shown in Fig. 13.

11.1.5 Between Original/Repair—Mark an “X” in the box beside between original/repair if delamination has occurred between the outermost coat of the original coating system and the innermost coat of the repair system. A diagram of delamination between original/repair is shown in Fig. 13.

11.1.6 Within Original System—Mark an “X” in the box beside within original system if delamination has occurred between any layers of the original coating system.

11.1.7 To Primer Coat—Mark an “X” in the box beside to primer coat if delamination has occurred between the innermost coat of the original coating system and the shop primer. A diagram of delamination to primer coat is shown in Fig. 13.

11.1.8 To Steel Substrate—Mark an “X” in the box beside to steel substrate if all coatings have separated from the surface of the hull leaving the bare steel exposed. A diagram of delamination to steel substrate is shown in Fig. 13.

11.1.9 Organic Odor from Delamination Area—The inspector should determine if there is an organic odor emanating from the delaminated area. If there is an odor from an organic solvent (such as MEK or hi-flash naphtha), circle the “Y.” If there is no organic odor, circle the “N.”

11.1.10 Sample Taken—If samples are taken, circle the “Y” ; if not, circle the “N.” Samples may be taken by removing some of the delaminated paint chips and placing them into a small container. The container should be labelled with the area number, ship name and hull number, date, and inspector’s name.

11.2 Blistering:

11.2.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1) and Method D 714, enter the number of the diagram that most closely approximates the overall extent of blistering. If there is no blistering in this inspection area, enter the number “0” (zero), and proceed to 11.3.

11.2.2 Size—Using the method in accordance with Method D 714, enter the number that most closely approximates the size of the largest blister in the inspection area.

11.2.3 Density—Using the method in accordance with Method D 714, enter the number that most closely approximates the highest blister density in the inspection area.

11.2.4 Broken Blisters, Percent—Visually approximate the percentage of broken blisters and enter that number in the box to the right. If none of the blisters are broken, enter the number “0.” To complete 11.2.5, 11.2.6, and 11.2.7 of the inspection, the inspector must break open a few of the blisters using a knife or other sharp object.

11.2.5 Organic Odor in Blisters—When the blisters are broken, the inspector should note whether the blisters contain liquid. If the blisters do contain liquid, the inspector should smell the liquid to determine if the liquid has an organic odor (that is, ketone). If the liquid does have an organic odor, circle the “Y” next to organic odor in blisters. If there is no organic odor, or if the blisters do not contain liquid, circle the “N.”

11.2.6 Blisters Contain Water—If the blisters contain liquid and the liquid does not have an organic odor, circle the “Y” next to blisters contain water. If none of the blisters contain liquid, circle the “N.”

11.2.6.1 pH—If “Y” is circled in response to blisters contain water, then determine the pH of the water using pH paper or pH meter and enter the pH value in the box to the right of pH.

11.2.7 Corrosion Under Blisters—Look at the substrate beneath the blisters that have just been broken open. If any part of the substrate beneath these blisters is corroded, circle the “Y” next to corrosion under broken blisters. If none of the substrate beneath these broken blisters is corroded, circle the “N.”

11.3 Checking:

11.3.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of cracking. If there is no cracking in this inspection area, enter the number “0” (zero), and proceed to 11.4.

11.3.1.1 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of cracking within the affected area. If the overall extent box above is marked with a “0” (zero), leave the extent within affected area box blank.

11.4 Checking:

11.4.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1) and Test Method D 660, enter the number of the diagram that most closely approximates the overall extent of checking. If there is no checking in this inspection area, enter the number “0” (zero), and proceed to 11.5.

11.4.1.1 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1), enter the letter of the diagram that most closely approximates the extent of checking within the affected area. If
11.5 Flaking:

11.5.1 Overall Extent of Failure—Using the overall extent of failure diagrams (diagrams and instructions for use in 4.1), enter the number of the diagram that most closely approximates the overall extent of flaking. If there is no flaking in this inspection area, enter the number “0” (zero), and proceed to 11.6.

11.5.1.1 Extent Within Affected Area—Using the extent within affected area diagrams (diagrams and instructions for use in 4.1) and Test Method D 772, enter the letter of the diagram that most closely approximates the extent of flaking within the affected area. If the overall extent of failure box as specified in 11.5.1 is marked with a “0” (zero), leave the extent within affected area box blank.

11.5.2 Severity—Use the photographic reference standard in accordance with Test Method D 772 to determine the degree of flaking. Enter the number of the photographic reference standard (2, 4, 6, or 8) that most closely approximates the degree of flaking on the inspection surface.

11.6 Sags or Curtains—Sags or curtains can occur on a vertical surface when paint is applied too thickly. Gravity will cause the paint to move down the vertical surface to form either a continuous ridge across the surface (curtain) or a running stream down the surface (sag). If either sags or curtains have occurred, circle the “Y.” If there is no evidence of sags or curtains, circle the “N.”

11.7 Chalking—Chalking is characterized by the presence of loose removable powder, evolved from the paint film itself, at or just beneath the surface. Chalking may be detected by rubbing the fingertips across the film. If chalking is present, circle the “Y.” If there is no evidence of chalking, circle the “N.”

11.8 Presence of Oil/Grease/Smoke—The inspector should examine the inspection area for the presence of oil or grease marks (usually the result of spills) and for smoke stains (usually the result of smoke from exhaust stacks). If oil or grease marks or smoke stains are present in the inspection area, the inspector should circle “Y”; otherwise, the “N” should be circled.

11.9 Bleeding—Bleeding is said to occur when the color of an undercoat (usually a darker color) extends or bleeds through the surface of a topcoat (usually a lighter color). If bleeding has occurred in the inspection area, the inspector should circle the “Y.” If there is no evidence of bleeding, the “N” should be circled.

11.10 Fading—Fading is defined as the loss of brightness or vividness of color. Fading is usually more apparent with darker colors. If fading has occurred in the inspection area, the inspector should circle the “Y,” otherwise, the “N” should be circled.

11.11 Knife Test—Using a craftsman’s knife with a curved blade and holding the blade at a 30° angle to the substrate, cut a narrow ribbon of coating from an undamaged portion of the inspection area.

11.12 Erosion—Erosion is the wearing away of a paint film over a period of time to expose the substrate or undercoat. If erosion has occurred in the inspection area, circle the “Y.” If there is no evidence of erosion, circle the “N.”

11.13 Discoloration—Discoloration is characterized by a brown or black stain in the paint film that occurred because the tank was carrying fuel. Usually, there will be a line across the vertical surfaces of the tank below which discoloration has occurred and above which there is no discoloration. This line would be left by the level in the tank. If discoloration is present, circle the “Y.” If there is no discoloration, circle the “N.”

11.14 Softening—Softening can be the result of organic fuel cargo. Softening can be detected by pressing the edge of your fingernail into the paint film. If an impression is made, circle “Y.” If your fingernail does not penetrate the surface, softening has not occurred and the “N” should be circled.

11.15 Valves, Piping, and Heating Coils Present—If valves, piping, or heating coils are attached to or supported from the inspection area surface, circle “Y.” If no valves, piping, or heating coils are attached to or supported from the inspection area surface, circle “N” and proceed to 11.16.

11.15.1 Coating Damage in Adjacent Areas—If valves, piping, or heating coils are present, the inspector should examine the adjacent painted areas. If any damage (that is, delamination, blistering, corrosion, etc.) to the paint system has occurred, circle the “Y.” If there is no damage to the paint, circle the “N.”

11.16 Stiffeners Present—Horizontal and vertical stiffeners are structural supports that may be present in the tank to add strength and rigidity. If stiffeners are attached to the inspection area surface, circle the “Y.” If stiffeners are not present, circle the “N” and proceed to 11.17.

11.16.1 Coating Damage Behind Stiffeners—If stiffeners are present, the inspector should examine the adjacent painted area. If any damage (that is, delamination, blistering, corrosion, etc.) to the paint system has occurred, circle the “Y.” If there is no damage to the paint, circle the “N.”

11.17 Anodes Present—If the anodes are attached to the inspection area surface, circle the “Y.” If there are no anodes attached to the inspection area surface, circle the “N” and proceed to 11.18.

11.17.1 Coating Damage in Adjacent Areas—If anodes are present, the inspector should examine the adjacent painted area. If any damage (that is, delamination, blistering, corrosion, etc.) to the paint system has occurred, circle the “Y.” If there is no damage to the paint, circle the “N.”

11.17.2 Anodes Functioning—There are two situations when the anodes can be said to be functioning: (1) if the anode itself is corroded and has lost mass and shape, and (2) if both the anode itself and all surfaces in the tank are completely free of corrosion. If either of these situations exists, circle the “Y.” The anode is not functioning if corrosion is present on the tank surfaces but the anode itself is free of corrosion. In this latter situation, circle the “N.”

Note 3—Do not confuse superficial dirt on the anode with corrosion.

11.18 Excessive Wear/Mechanical Damage—The inspector should examine the inspection area for signs of excessive wear.
or mechanical damage. Excessive wear is characterized by a wear path through a coated area caused by heavy foot or vehicular traffic over the same path. Mechanical damage is characterized by scrapes or cuts through a coated area caused by dropping tools, dragging heavy equipment, etc.

11.18.1 Non-skid Areas—If excessive wear or mechanical damage has occurred on a non-skid surface in the inspection area, the inspector should circle the “Y;” otherwise, the “N” should be circled.

11.18.2 Other Areas—If excessive wear or mechanical damage has occurred on any surface that is not a non-skid surface, the inspector should circle the “Y;” otherwise, the “N” should be circled.

12. Acceptability

12.1 If the cut portion of the coating ribbons or delaminates between layers, circle the “Y.” If there is no evidence of ribboning or delamination between layers, circle the “N.” If “Y” is circled, identify the delamination layer by marking the appropriate delamination box (IIA, 2 to 7) in Fig. 4, Fig. 5, and Fig. 7 and IIIA, 2 to 7 in Fig. 6.

12.1.1 Topcoat—Mark an “X” in the box beside topcoat if topcoat delamination has occurred. Topcoat delamination has occurred if only the outermost coating has separated from all undercoats. A diagram of topcoat delamination is shown in Fig. 13.

12.1.2 Within Repair System—Mark an “X” in the box beside within repair system if delamination has occurred between layers of the repair system excluding delamination between the topcoat and the undercoat. (This is topcoat delamination.) The repair system is defined as any coating system that is applied on top of the original coating system. Therefore, if the original coating system has not been overcoated, delamination within the repair system is not possible. A diagram of delamination within the repair system is shown in Fig. 13.

12.1.3 Between Original/Repair—Mark an “X” in the box beside between original/repair if delamination has occurred between the outermost coat of the original coating system and the innermost coat of the repair system. A diagram of delamination between original/repair is shown in Fig. 13.

12.1.4 Within Original System—Mark an “X” in the box beside within original system if delamination has occurred between any layers of the original coating system. A diagram of delamination within original system is shown in Fig. 13.

12.1.5 To Primer Coat—Mark an “X” in the box beside to primer coat if delamination has occurred between the innermost coat of the original coating system and the primer coat. A diagram of delamination to primer coat is shown in Fig. 13.

12.1.6 To Steel Substrate—Mark an “X” in the box beside the steel substrate if all coatings have separated from the surface of the hull leaving bare steel exposed. A diagram of delamination to steel substrate is shown in Fig. 13.

13. Measured Properties

13.1 Dry Film Thickness—Make dry film thickness (DFT) measurements using a properly calibrated magnetic gage. Perform measurements and calibration in accordance with SSPC-PA-2. Record each measurement to include three individual measurements within each spot measurement. The separate spots where DFT measurements are taken must be clean and dry with an intact coating undamaged by fouling, corrosion, etc. If a separate spot is not suitable for DFT measurements, proceed to the nearest suitable location. If the entire inspection area is not suitable for DFT measurements leave all boxes blank.

13.1.1 Each line on the inspection form is intended to hold all of the readings to include three individual readings within a spot reading.

13.2 There are enough lines present on the inspection forms to hold readings for A: (1) 6000-ft² underwater hull inspection area, (2) 1800-ft² topside and superstructure inspection area, and (3) 1000-ft² tanks and voids inspection area.

13.3 If the inspection area is larger than that specified in the applicable area in 13.2, circle the “Y” next to Number 1, take more DFT readings. On a separate sheet of paper, enter all of the additional readings. Also include the area number (of the inspection area), date, ship name, hull number, and inspector’s name. If the inspection area is not larger than that specified in the applicable area in 13.2, circle the “N” next to Number 1.

13.4 Dielectric Shields—For underwater hull, the inspector should inspect both the primary and secondary dielectric shields and answer yes (“Y”) or no (“N”) to questions A to D, F, and G. Measure the dry film thickness (DFT) of both the primary and secondary dielectric shields and record the results in the boxes next to E, Film Thickness (mils). If only one dielectric shield is present, record answers under primary (PRIM). Leave the columns under secondary (SEC) blank.

13.4.1 Blistering—If blistering is present, circle “Y.” If there are no blisters, circle “N.”

13.4.2 Delamination—If delamination is present, circle “Y.” If there is no delamination, circle “N.”

13.4.3 Fouling—If any type of fouling is present, circle “Y.” If the dielectric shield is free of fouling, circle “N.”

13.4.4 Corrosion:

13.4.4.1 General—If general corrosion is present, circle “Y;” otherwise, circle “N.”

13.4.4.2 Pitting—If pitting corrosion is present, circle “Y;” otherwise, circle “N.”

13.4.5 Dry Film Thickness—Enter the DFT measurements in the appropriate box.

13.4.6 Calcareous Deposit—If any calcareous (white, calcium-like) deposits are present, circle “Y.” If none are present, circle “N.”

13.4.7 Erosion—If there is evidence of erosion, circle “Y.” If no evidence of erosion is present, circle “N.”

14. Recommendations

14.1 Any recommendations deemed by the inspector to apply to the conditions observed or reported on the form should be entered here. If the inspector has no recommendations, state “none” in the section.

14.2 The last line on the form provides the documentation whether an officer received a copy of the inspection form. The officer’s signature following “Acknowledged by” indicates the ship’s representative did receive a copy of the inspection results. It is not meant to indicate his agreement or disagreement of the information on the form.
15. Keywords

15.1 coating system; inspection; ships

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Standard Specification for
Insulation Resistance Monitor for Shipboard Electrical
Motors and Generators

This standard is issued under the fixed designation F 1134; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers monitoring devices (monitors) for the automatic detection and signaling of low insulation
resistance values in idle electrical motors or generators, or both.
1.2 Monitors are intended for permanent installation in both existing or new panels and controller enclosures designed for
marine application.
1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information
only.
1.4 The following safety hazards caveat pertains only to the test method described in this specification: This standard does
not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this
standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior
to use.

2. Referenced Documents
2.1 UL Standard:
UL 94 Test for Flammability of Plastic Materials for Parts in Devices and Appliances
2.2 IEEE Standards:
IEEE 45 Recommended Practice for Electrical Installations on Shipboard
IEEE 100 Standard Dictionary of Electrical and Electronics Terms
2.3 Government Standard:
Title 46 Code of Federal Regulations Shipping

3. Terminology
3.1 Definitions—In general, definitions shall be in accordance with IEEE 100.
3.2 Definitions of Terms Specific to This Standard:
3.2.1 idle machine—rotary machine, when not rotating, owing to the absence of energy.
3.2.2 monitor—device, generally located in a motor starter, control panel, or main switchboard, that senses the leakage
resistance of electrical machine windings to ground, while the monitored machine stands idle.

4. Monitor Classification
4.1 Type—The insulation resistance monitors covered by this specification shall be of the following types:
4.1.1 Type I—Alternating current motor monitors.
4.1.2 Type II—Alternating current generator monitors.
4.1.3 Type III—Direct current motor monitors.
4.1.4 Type IV—Direct current generator monitors.
4.2 Duty Rating—All monitors shall be capable of continuous duty operations as defined in accordance with IEEE 100.

5. Ordering Information
5.1 Monitoring devices shall be ordered by including the following information:
5.1.1 Purpose or Use of Monitor(s)—Application as motor or generator monitor.
5.1.2 Line voltage and frequency.
5.1.3 Control voltage and frequency.
5.1.4 Type of starter (if motor monitor).
5.1.5 Winding configuration (if motor monitor).
5.1.6 Location of monitor.
5.1.7 Sensitivity—Set for 1 megohm (optional setting, if requested, from 0.1 to 5 MΩ).
5.1.8 Remote monitoring devices.
5.1.9 Special options requested (that is, test buttons, elevated ambient temperature usage, and so forth.).

6. Materials and Manufacture
6.1 General—Materials used in the construction of insulation resistance monitors are to be manufactured and tested in
accordance with IEEE 45. Materials conforming to other
recognized standards will be subject to approval by the
procuring agency, provided they are not less effective.
6.2 Flame-Retardant Materials—Enclosure materials used
in the construction of the monitors are to be flame-retardant in
accordance with UL94, and have a minimum flame rating of
94V-1 for monitors being installed within a motor controller
enclosure, or switchgear-type enclosure, or a minimum rating
of 94-SV for monitors not installed within such an enclosure.
6.3 Electrical Insulation—Electrical insulation materials
used and application thereof shall be in accordance with the
requirements of IEEE 45.
6.4 Current Carrying Terminals—All monitor current car-
yring terminals shall be made of corrosion resistant material in
accordance with CFR 46, Subchapter J.
6.5 Electrical Isolation—Monitors shall isolate their meas-
uring circuit from the line voltage, while the motor is
operating, by the use of an integral isolating relay.

7. General Design Requirements
7.1 Environment:
7.1.1 Temperature—The rating of the monitor shall be
based on an ambient temperature of 50°C (122°F).
7.1.1.1 Operating Temperature Range—Monitors shall op-
erate over the range from 0 to 50°C (32 to 122°F). (See 10.1.2
for operation range.)
7.1.2 Sealing—The monitor housing upon final assembly
shall protect the internal components against foreign matter
and shall be so constructed as to prevent tampering.
7.1.3 Inclination—Monitors shall operate when inclined at
any angle up to 60° in any direction from the normal operating
position.
7.1.4 Humidity—Monitors shall operate at a constant rela-
tive humidity of up to minimum 90 %.
7.1.5 Vibration—Monitors shall operate in the presence of
acceptable operational shipboard vibration, without mechani-
cal damage, control chatter, or other defects.
7.2 Operating Voltage/Accuracy:
7.2.1 Monitor Relays—Monitor relays shall pick up and
hold from 80 % rated line voltage upwards with the coil at its
maximum operating temperature and shall operate satisfac-
torily in the range from 80 to 120 % of rated line voltage.
7.2.2 Design Voltage Characteristics—Monitors shall be
designed for application on 60 Hz ac and dc current systems
and be designed to operate on electrical systems having
standard voltages acceptable to the U.S. Coast Guard. (See 46
CFR 111.)
7.2.3 Operating Accuracy—Monitors shall alarm within
± 10 % of the ordered set point indicated on the label plate,
when operated in accordance with 7.2.1.
7.3 Installation Instructions:
7.3.1 The monitor vendor shall submit complete installa-
tion instructions with each monitor shipped, including drawings as
necessary, denoting the following information:
7.3.1.1 Application as a motor or generator monitor.
7.3.1.2 Line voltage level to be applied to monitor.
7.3.1.3 Type designation of monitor supplied.
8. Construction Specifications
8.1 General:
8.1.1 Monitors shall be designed for ease of installation
requiring no special tools and shall be fitted with a fastening
device compatible with the vibration criteria established for
marine applications.
8.1.2 Indication of a condition representing a low insulation
value as detected by the monitor shall be displayed by means
of an illuminated device mounted on the body of the monitor.
8.1.3 The monitor shall include voltageless terminals to
which remotely located audible or visual indicators, or both,
can be connected through the use of control cabling. Relay
contacts for this function shall have contacts with a switching
power of 1000 W ac, 100 W dc for a resistive load.
8.1.4 Electrical interface with the monitor shall be through
the use of terminals (or terminal strips), screws and lugs
(solderless crimp or solder types). Splicing will not be used.
The size of terminals and conductors for interfacing the
monitoring shall be suitable to carry the maximum currents
expected during operation.
8.1.5 The monitor’s sensing circuit should be limited to the
following levels:
8.1.5.1 Voltage—not to exceed 24 V.
8.1.5.2 Current—not to exceed 100 µA.
8.1.6 Monitors shall be designed to provide a range of
insulation resistances to be monitored based on the type of
monitor ordered. However, each individual monitor shall be
designed for one or two specific resistance values, and these
values shall be marked on the label plate of the device.

9. Workmanship, Finish, and Appearance
9.1 All workmanship shall be of acceptable commercial
marine standard in all respects and all materials, components or
parts specified shall be new and unused, except for normal
testing, as required.

10. Test Methods
10.1 Routine Tests—Subject each monitor offered for deliv-
er to the following tests:
10.1.1 Visual and mechanical examination.
10.1.2 Operational performance test.
10.2 Visual and Mechanical Examination—Examine the
monitor devices to verify that the materials, design, construc-
tion, dimensions, weight, marking, and workmanship are in
conformance with the vendor’s drawings.
10.3 Operational Performance—Test the completely as-
sembled devices of all functions over the specified line voltage
range (rated line voltage ±20 %). Accuracy of alarm shall be
as stated in 7.2.3.

11. Product Marking
11.1 Each monitor device shall be identified with a perma-
nently applied and clearly marked labelplate indicating the
following information:
11.1.1 Manufacturer’s name and address.
11.1.2 Type designation.
11.1.3 Applicable specification number(s).
11.1.4 Serial number.
11.1.5 Monitor supply voltage.
11.1.6 Monitor control voltage.
11.1.7 Insulation resistance value below which the alarm should be activated.
11.1.8 Ratings and configurations of alarm relay contacts.
11.1.9 Temperature rating.
11.1.10 Date of final test.

12. Keywords

12.1 electrical generator; electrical motors; insulation; low insulation resistance values; marine controller enclosures; resistance monitor; shipboard generator; shipboard motors

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1. Scope

1.1 This specification describes the manufacturing requirements for spray shield stock and the fabrication and installation requirements for spray shields made from that stock.

1.1.1 Sections 2-14 address the manufacturing requirements for the spray shield stock. Annex A1 addresses the fabrication and installation requirements for the spray shields.

1.1.2 Fig. 1 shows the typical construction of a spray shield. Figs. 2-6 show methods of installation of a spray shield on various mechanical joints.

1.2 The shields are intended for use around mechanical joints (flanged, bolted unions, and so forth) in liquid piping systems to prevent the impingement of flammable liquid on hot surfaces or fluids onto electrical switchboards and components resulting from a leak in the mechanical joint.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip
A 276 Specification for Stainless Steel Bars and Shapes
A 580 Specification for Stainless Steel Wire
B 134 Specification for Brass Wire
B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire
B 166 Specification for Nickel-Chromium-Iron Alloys (UNS N 06600, N 06601, and N 06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N 06617) Rod, Bar, and Wire
D 1388 Test Method for Stiffness of Fabrics
D 1424 Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus
D 1682 Test Methods for Breaking Load and Elongation of Textile Fabrics
D 1777 Method for Measuring Thickness of Textile Materials
D 3389 Test Method for Coated Fabrics Abrasion Resistance (Rotary Platform, Double-Head Abrader)
D 3776 Test Methods for Mass Per Unit Area (Weight) of Fabric
D 3786 Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method
D 3951 Practice for Commercial Packaging
F 501 Test Method for Aerospace Materials Response to Flame, With Vertical Test Specimen (For Aerospace Vehicles Standard Conditions)

2.2 American Association of Textile Chemists and Colorists Standards:
AA TCC-22 Water Repellency, Spray Test
AA TCC-35 Water Resistance, Rain Test
AA TCC-127 Water Resistance, Hydrostatic Pressure Test

2.3 Military Standards:
MIL-C-20079 Cloth, Glass, Tape, Textile Glass and Thread, Glass
MIL-C-20696 Cloth, Coated, Nylon Waterproof

2.4 Federal Standard:
WW-C-440 Clamps, Hose (Low Pressure)

3. Ordering Information

3.1 ASTM designation and year of issue,
3.2 Length and width required (see 7.1), and
3.3 Type of stainless steel (see 4.1).

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.


2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

3 Withdrawn.

4 Available from American Association of Textile Chemists and Colorists (AA TCC), One Davis Dr., P.O. Box 12215, Research Triangle Park, NC 27709-2215.

3.4 Type of lacing hardware required (see 4.1.1).

4. Materials and Manufacture

4.1 Lacing hooks, lacing rings, and lacing washers (see Fig. 7) shall be constructed of stainless steel in accordance with Specifications A 176, A 276, or A 580.

4.1.1 Lacing rings may be used instead of lacing hooks where practicable or preferable (see 3.3).

4.1.2 Lacing washers for fastening hooks or rings shall be two-hole washers.

4.2 Stitch wire (Piece 5 in Table 1) shall be constructed of stainless steel in accordance with Specification A 580.

4.3 The aluminized glass cloth, thread, and the protective outer jacket shall be constructed of material as specified in Table 1 and Table 2.

5. Physical and Mechanical Properties

5.1 The physical and mechanical properties for the aluminized glass cloth, thread, and protective outer jacket shall be as specified in Table 1 and Table 2.

6. Requirements

6.1 If lacing hooks or rings are of the type that fasten by stitching, the hooks or rings shall be attached to the backup washers using a wire stitch machine and wire (Pieces 5 or 8 in Table 1).

6.2 Lacing anchor/self-locking washer-type systems shall not be used on spray shields.

7. Dimensions and Permissible Variations

7.1 The material for shields shall be standardized as given in Table 3 tolerances to be +1/4 in. (6 mm) and −0 in. for width.
8. Workmanship, Finish, and Appearance

8.1 The seam on both sides of the spray shield shall be intact.

8.1.1 On drawstring-type shields, there shall be ample overlap in the seam to allow wire to be run through the entire length of the shield.

8.2 There shall be no tears in the uncovered aluminum portion of the shield where contact is made with the mechanical joint (see Fig. 1).

8.3 There shall be no tears in the protective outer jacket such that the aluminized glass cloth underneath is exposed.

8.4 There shall be no holes or openings of any kind in the shields other than those made by sewing or the attachment of lacing hooks or rings.

9. Sampling, Selection, and Number of Specimens

9.1 Unless otherwise specified, the sampling of, selection of, and number of specimens for the aluminized glass cloth, thread, and protective outer jacket shall be as specified in the applicable test methods listed in Table 1 and Table 2.

10. Test Methods

10.1 The methods for testing the aluminized glass cloth, thread, and protective outer jacket shall be as specified in Table 1 and Table 2.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the contractor is responsible for performing inspections to determine conformance to the requirements specified in Section 8 of this specification.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Product Marking

13.1 Indelible stamp denoting the width of the shield shall be placed at 24-in. (610-mm) intervals on the visible foil side of the shield so that it will be visible when the shield is rolled and packaged.

14. Packaging and Package Marking

14.1 The packaging, packing, and marking of containers shall be in accordance with Practice D 3951, with the exceptions noted in 14.1.1 and 14.1.2.

14.1.1 Each container used for spray shield packaging shall contain installation instructions as shown in Annex A2.

14.1.2 Metal strapping shall not be used for container closure and reinforcement.

14.2 Installed lacing hooks and aluminized cloth shall be so packaged that there shall be no damage to the cloth during shipment.

15. Keywords

15.1 lacing; mechanical joints; shield; spray shield
FIG. 5 Spray Shield for Butterfly Valve

FIG. 6 Spray Shield for Valve Bonnet

FIG. 7 Optional Lacing Hardware
### TABLE 1 List of Material

<table>
<thead>
<tr>
<th>Piece Number</th>
<th>Description</th>
<th>Quality</th>
<th>Material</th>
<th>Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hook, lacing</td>
<td>as required</td>
<td>stainless steel</td>
<td>ASTM A 176, A 276, A 580</td>
<td>see 4.1</td>
</tr>
<tr>
<td>2</td>
<td>Cloth, aluminum foil, glass</td>
<td>as required</td>
<td>glass/aluminum</td>
<td>MIL-C-20079</td>
<td>Type I, Class 10</td>
</tr>
<tr>
<td>3</td>
<td>Thread</td>
<td>as required</td>
<td>glass</td>
<td>MIL-C-20079</td>
<td>Class III, Class 3 (for machine sewing) white, Size 5 Z-twist, three-ply</td>
</tr>
<tr>
<td>4</td>
<td>Washer, blank</td>
<td>as required</td>
<td>stainless steel</td>
<td>ASTM A 176, A 276 ¾-in. diameter × 0.030 in. thick</td>
<td>see 6.1</td>
</tr>
<tr>
<td>5</td>
<td>Wire, stitch</td>
<td>as required</td>
<td>stainless steel</td>
<td>ASTM A 580</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Label, identification</td>
<td>as required</td>
<td>Cres 201</td>
<td>WW-C-440</td>
<td>Type F</td>
</tr>
<tr>
<td>7</td>
<td>Clamp, hose</td>
<td>as required</td>
<td>Cr-Ni-alloy</td>
<td>ASTM B 134</td>
<td>17 or 18 gage</td>
</tr>
<tr>
<td>8</td>
<td>Wire</td>
<td>as required</td>
<td>Cu-Ni-alloy</td>
<td>ASTM B 166</td>
<td>17 or 18 gage</td>
</tr>
<tr>
<td>9</td>
<td>Rings, lacing</td>
<td>as required</td>
<td>stainless steel</td>
<td>ASTM A 276, A 580</td>
<td>see 4.1.1</td>
</tr>
<tr>
<td>10</td>
<td>Fabric, protective outer jacket</td>
<td>as required</td>
<td>fiberglass cloth/silicone coated fiberglass</td>
<td>see Table 2</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 2 Material Data—Protective Outer Jacket

<table>
<thead>
<tr>
<th>Typical Properties</th>
<th>Silicone Coated Fiber-glass Cloth Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Style</td>
<td>Satin</td>
</tr>
<tr>
<td>Weight, oz/yd²</td>
<td>16.10</td>
</tr>
<tr>
<td>Thickness, in.</td>
<td>0.018</td>
</tr>
<tr>
<td>Count, W × F</td>
<td>54 × 48</td>
</tr>
<tr>
<td>Breaking strength, lb/in. W × F</td>
<td>625 × 625</td>
</tr>
<tr>
<td>Weave</td>
<td>8 harness</td>
</tr>
<tr>
<td>Width, in.</td>
<td>50 or 60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coated Properties</th>
<th>Test Methods</th>
<th>Product Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating</td>
<td>per standard</td>
<td>Balanced, cured</td>
</tr>
<tr>
<td>Color</td>
<td>Silver</td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>Test Method D 1777</td>
<td>0.019</td>
</tr>
<tr>
<td>Weight, oz/yd²</td>
<td>Test Method D 3776</td>
<td>20.00</td>
</tr>
<tr>
<td>Flame resistance</td>
<td>Test Method F 501</td>
<td>0' flame (self-extinguishing)</td>
</tr>
<tr>
<td>Breaking strength, lb/in. W × F</td>
<td>Test Methods D 1682</td>
<td>470 × 410</td>
</tr>
<tr>
<td>Tear strength, lb/in. W × F</td>
<td>Test Methods D 1424</td>
<td>35 × 31</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>Test Method D 3389 (CS-10, 500 GMS)</td>
<td>200 × 300 min</td>
</tr>
<tr>
<td>Mullen hydrostatic, psi</td>
<td>AATCC-127</td>
<td>20 min</td>
</tr>
<tr>
<td>Water resistance, rain test</td>
<td>AATCC-35</td>
<td>Pass 0 GMS ≤ 5 ft, Pass 0.10 GMD ≤ 8 ft</td>
</tr>
<tr>
<td>Water repellancy, spray test</td>
<td>AATCC-22</td>
<td>Pass 100 rating</td>
</tr>
<tr>
<td>Mullen burst, psi</td>
<td>Test Method D 3786</td>
<td>800 min</td>
</tr>
<tr>
<td>Clark stiffness, CM</td>
<td>Test Method D 1388</td>
<td>18.0 max</td>
</tr>
<tr>
<td>Oil resistance</td>
<td>MIL-C-20696</td>
<td>Pass</td>
</tr>
<tr>
<td>Aromatic hydrocarbon fluid resistance</td>
<td>MIL-C-20696</td>
<td>Pass</td>
</tr>
</tbody>
</table>
ANNEXES

(Mandatory Information)

The requirements of this section apply only to the fabrication and installation of the spray shields.

A1. FABRICATION OF SPRAY SHIELDS

A1.1 To determine spray shield length and width, the flange that is to be shielded shall be measured as follows:

A1.1.1 Shield length:
Measure the circumference of the flange. Add an overlap of \( \frac{1}{4} \) of the circumference measurement, with the maximum being 8 in. (203 mm) and the minimum being 1 in. (25 mm).
A1.1.1.1 To prevent dirt accumulation, the overlap shall be pointed downward (see Fig. A1.1).

A1.1.2 Shield width:
Measure from the inside edge of the bolt to the edge of the flange (A). Measure the combined flange thickness (B). In the following illustration, this would be “A + B + A” as a minimum requirement.

A1.1.2.1 If the measured width contains a fraction, the next wider shield stock shall be used (see 7.1). For example, if the measured width is 5\(\frac{1}{2}\) in. (140 mm), 6-in. (152-mm) wide shield stock shall be used.

<table>
<thead>
<tr>
<th>Length, ft (m)</th>
<th>Width, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 (9)</td>
<td>5 (127)</td>
</tr>
<tr>
<td>30 (9)</td>
<td>6 (152)</td>
</tr>
<tr>
<td>30 (9)</td>
<td>7 (178)</td>
</tr>
<tr>
<td>30 (9)</td>
<td>8 (203)</td>
</tr>
<tr>
<td>20 (6)</td>
<td>9 (229)</td>
</tr>
<tr>
<td>20 (6)</td>
<td>10 (254)</td>
</tr>
<tr>
<td>20 (6)</td>
<td>11 (279)</td>
</tr>
<tr>
<td>20 (6)</td>
<td>12 (305)</td>
</tr>
</tbody>
</table>

NOTE 1—Maximum overlap is 8 in. (203 mm).
NOTE 2—Minimum overlap is 1 in. (25 mm).
A2. INSTALLATION OF SPRAY SHIELDS

A2.1 General Installation:
A2.1.1 The shield shall be centered on the joint, wrapped snugly around the sides of the joint, and laced tightly with wire.

A2.2 Standard Installation:
A2.2.1 Cut two lengths of lacing wire 6 in. (152 mm) longer than the length of the shield.
A2.2.2 Cut away seam material on each side of overlap and insert lengths of wire into seams on both sides of shield until the wire emerges at the other end.
A2.2.3 Wrap shield around flange with aluminized cloth on the inside.
A2.2.4 Fold shield edges down over flange bolts.
A2.2.5 Twist ends of wire together sufficiently to maintain tightness, cut excessive wire, and fold down to be flat on shield. If additional tightness is required, use the lacing hooks shown in Fig. 7.

A2.3 Optional Installation (Lacing Hooks or Rings):
A2.3.1 Cut away seam material on each side of overlap. There shall be a 5/8-in. (16-mm) space between the end of shield overlap and the first pair of lacing hooks.
A2.3.1.1 Remove lacing hooks that would be under the overlap.
A2.3.2 Wrap shield around flange with aluminized glass cloth on the inside.
A2.3.3 Fold shield edges down over flange bolts.
A2.3.4 String wire through hooks on both sides and pull tight to secure shield in place.
A2.3.5 Twist end of wire together sufficiently to maintain tightness, cut excessive wire, and fold down to be flat on shield.
Standard Specification for Steam Traps and Drains

This standard is issued under the fixed designation F 1139; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides the minimum requirements for the design, fabrication, pressure rating, marking, and testing of steam traps and drains.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test method portion of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ANSI Standards:
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable-Iron Screwed Fittings
B16.4 Cast-Iron Screwed Fittings
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings Socket-Welding and Threaded
B16.15 Cast Bronze Screwed Fittings
B16.18 Cast Bronze Solder-Joint Pressure Fittings
B16.22 Wrought Copper and Bronze Solder-Joint Pressure Fittings
B16.24 Bronze Flanges and Flanged Fittings
B16.34 Steel Valves, Flanged and Butt weld Ends
B31.1 Power Piping

2.2 MSS Standards:
SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions
SP-51 150 lb Corrosion Resisting Cast Flanges and Flanged Fittings

2.3 ASME Standards:
ANSI/ASME PTC 39.1 Condensate Removal Devices for Steam Systems
ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Pressure Vessels
ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

3. Definitions of Terms Specific to This Standard

3.1 cold condensate capacity (QC)—maximum mass of condensate that the steam trap/drain can discharge in 1 h at a given pressure and temperature, the trap/drain being fully open (lb/h (kg/h)).

3.2 drain—device having no moving parts permitting the discharge of fluids at a fixed or adjustable rate.

3.3 hot condensate capacity (QH)—maximum mass of condensate that a steam trap/drain can discharge in 1 h at a given pressure and temperature (lb/h (kg/h)).

3.4 hydrostatic proof test (PTHP)—test used in determining maximum allowable pressure (PMA) and maximum allowable temperature (TMA) (lb/in.² (kg/mm²)).

3.5 maximum allowable pressure (PMA)—maximum pressure that the shell of the steam trap/drain can withstand permanently at a given temperature (lb/in.² (kg/mm²)).

3.6 maximum allowable temperature (TMA)—maximum temperature to which the shell of the steam trap/drain can be raised permanently (°F (°C)).

3.7 maximum differential pressure (ΔPMX)—maximum difference between operating pressure and operating back pressure (lb/in.² (kg/mm²)).

3.8 maximum operating back pressure (PMOB)—maximum permissible pressure measured at the outlet of the steam trap/drain allowing correct functioning (lb/in.² (kg/mm²)).

3.9 maximum operating pressure (PMO)—pressure for which a steam trap/drain is rated by the manufacturer.

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2 This specification was developed from Fluid Controls Institute Standards, 69-1 Pressure Rating Standards for Steam Traps and 85-1 Standard Production Test for Steam Traps.

3 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

4 Available from Manufacturer’s Standardization Society of the Valve and Fittings Industry, Inc., 1815 N. Fort Myers Dr., Arlington, VA 22209.

5 Available from American Society of Mechanical Engineers, Three Park Ave., New York, NY 10016-5990.
3.9.1 Discussion—This pressure is normally a function of the limitations related to the internal mechanism of the steam trap/drain (lb/in.² (kg/mm²)).

3.10 Maximum test pressure (PTMX)—maximum pressure applied to the steam trap/drain under test including its internal mechanism (lb/in.² (kg/mm²)).

3.11 Minimum differential pressure (ΔPMN)—minimum difference between operating pressure and operating back pressure (lb/in.² (kg/mm²)).

3.12 Operating back pressure (POB)—pressure measured at the outlet of the steam trap/drain under operating conditions (lb/in.² (kg/mm²)).

3.13 Operating differential pressure (ΔP)—difference between the operating pressure and the operating back pressure (lb/in.² (kg/mm²)).

3.14 Operating pressure (PO)—pressure measured at the inlet of the steam trap/drain under operating conditions (lb/in.² (kg/mm²)).

3.15 Operating temperature (TO)—temperature measured at the inlet of the steam trap/drain under operating conditions (°F (°C)).

3.16 Performance characteristics tests—tests carried out to determine the operational characteristics of a particular design of steam trap/drain.

3.17 Production tests—tests carried out by the manufacturer to confirm that the steam trap/drain functions correctly.

3.18 Steam trap—self-contained valve that automatically drains the condensate from a steam containing enclosure while remaining tight to live steam, or if necessary, allowing steam to flow at a controlled or adjusted rate.

3.18.1 Discussion—Most steam traps will also pass noncondensible gases while remaining tight to live steam.

4. Ordering Information

4.1 Orders for products under this specification shall include the following information as applicable:

4.1.1 Performance characteristics required—See Section 7.

4.1.2 Certification of performance characteristics if required. See Section 7.

4.1.3 Nominal pipe size.

4.1.4 Maximum operating pressure, psig (kPa). See 3.5.

4.1.5 Capacity, lb/h (kg/h) (QC or QH). See 3.17 and 3.18.

4.1.6 Connection type (that is, threaded, socket weld, flanged). See 5.2.1.

4.1.7 Materials—external and internal.

4.1.8 Type of trap/drain.

4.1.9 Maximum test pressure, psig (kPa). See 3.12.


4.1.11 Pressure differential (operating, maximum, or minimum, or combination thereof).

4.1.12 Notice for Acceptance Test—If the purchaser wishes to witness the production tests, this shall be specified in the order. See 8.2.

5. Materials and Manufacture

5.1 Materials:

5.1.1 The pressure ratings established under this specification are based upon materials of high quality produced under regular control of chemical and mechanical properties by a recognized process. The manufacturer shall be prepared to certify that his product has been so produced and that the mechanical and chemical properties thereof, as proved by test specimens and nondestructive testing or as documented by certifications from the producer or recognized distributor of these materials, are at least equal to the requirements of the appropriate specifications.

5.1.2 housings of traps/drains, and other parts or bolting, or combination thereof, used for pressure retention, shall be constructed of materials in accordance with ANSI/ASME B31.1 or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.1.3 Seals and parts, in addition to pressure containing parts and bolting used for pressure retention, shall be of materials suitable for the service.

5.1.4 Users are cautioned against applications with fluids that may react chemically with any materials used in these products.

5.1.5 For materials not having values of allowable stress tabulated in Section VIII, Division 1, allowable stresses shall be determined in accordance with the procedures outlined in Subsection C and Appendix P of Section VIII of the ASME Boiler and Pressure Vessel Code. Where it can be shown that the values of allowable stress listed for a particular material in one product form (because of similar chemistry, mechanical properties, directional properties, heat treatment, and so forth) are applicable to the same material in an unlisted product form, the listed values of allowable stress may be used.

5.2 Manufacture:

5.2.1 Steam traps/drains with end fittings in compliance with the following standards may be used within the pressure-temperature ranges permitted by the applicable standard provided the trap/drain housing (less end fittings) is satisfactory for these conditions:

5.2.1.1 ANSI B16.1, 5.2.1.2 ANSI B16.3, 5.2.1.3 ANSI B16.4, 5.2.1.4 ANSI B16.5, 5.2.1.5 ANSI B16.11, 5.2.1.6 ANSI B16.15, 5.2.1.7 ANSI B16.18, 5.2.1.8 ANSI B16.22, 5.2.1.9 ANSI B16.24, 5.2.1.10 ANSI B16.34, and 5.2.1.11 MSS SP-51.

5.2.2 Weld design details, welding, and nondestructive testing shall be in accordance with Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

6. Requirements

6.1 Pressure Rating and Design:
6.1.1 The maximum allowable pressure (PMA) and maximum allowable temperature (TMA) rating for steam traps/drains conforming to this specification shall be established by at least one of the following methods:

6.1.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII of the ASME Boiler and Pressure Vessel Code. If burst-type tests as outlined in UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of “B” to be used in determining the maximum allowable pressure shall be the maximum pressure to which the component was subjected without rupture. Safety of personnel shall be given serious consideration when conducting hydrostatic tests. Components that have been subjected to a hydrostatic proof test shall not be offered for sale.

6.1.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

6.1.1.3 Hydrostatic proof test of a representative production sample to establish the maximum allowable pressure (PMA) and maximum allowable temperature (TMA) rating as described in 8.1.

6.1.1.4 Extensive and successful performance experience under comparable service conditions with similarly proportioned components of the same or similar material may be used as a basis for rating provided all other provisions of this specification are met.

6.2 Production Tests:
6.2.1 The manufacturer shall production test every steam trap/drain as described in Section 8 by one of the following test methods:

6.2.1.1 Hydrostatic—See 8.2.
6.2.1.2 Steam—See 8.3.
6.2.1.3 Air—See 8.4.

6.2.2 Samples of the traps/drains shall be visually examined and dimensionally checked to ensure that the traps/drains correspond to this specification and are marked in accordance with Section 9.

6.2.3 Sample steam traps/drains shall be given an operational check steam test to ensure that they open to discharge condensate and close satisfactorily in accordance with 8.5. This test does not apply to labyrinth (orifice) steam traps/drains.

7. Performance Characteristics

7.1 A manufacturer may describe the operation of a particular type of steam trap or drain by referring to one or more of the performance characteristics. When this is done, the associated tests described in 8.6 must be performed on a representative production sample. A brief explanation of the derivation of each characteristic is given as follows. Further details on test methods are specified in Section 8.

7.1.1 Certification of performance characteristics shall be available if required by the purchaser (see 4.1.2).

7.2 Minimum Operating Pressure—The steam trap shall be tested to determine the minimum pressure (atmospheric or above) at which correct opening and closing will occur.

7.3 Maximum Operating Pressure (PMO) —The steam trap shall be tested to determine the maximum pressure at which correct opening and closing will occur.

7.4 Maximum Operating Back Pressure (PMOB) —The steam trap shall be tested to determine the maximum pressure permissible at the outlet of the device that allows correct functioning.

7.5 Air Venting Capability —The steam trap/drain shall be tested to determine its ability to discharge air and other noncondensable gases.

7.6 Operating Temperature (TO) —The steam trap/drain shall be tested to determine the temperature at which the device operates and, in particular, the temperature at which it passes its specified capacity.

7.7 Condensate Capacity (QH or QC) —The steam trap/drain shall be flow tested to determine its condensate capacity throughout its operating pressure range.

7.8 Live Steam Loss —The steam trap shall be tested to determine the amount of live steam lost through the trap.

8. Test Methods

8.1 Hydrostatic Proof Test —Establish the maximum allowable pressure (PMA) and temperature (TMA) rating using a hydrostatic proof test of a representative production sample, chosen in accordance with 6.1.1.3 and perform as follows:

\[
\text{PMA} = \frac{\text{PTHP}(T)}{5} \times \frac{\text{average tensile of test specimens of pressure retaining components}}{\text{stress value at design temperature}} \times \frac{\text{stress value at test temperature}}{
\]

8.1.1 Determine stress values in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code or ANSI B31.1.

8.1.2 Casting quality factor (f) shall be 1.0 for wrought materials and 0.8 for castings.

8.1.3 Gasket leakage during test does not constitute failure unless a result of rupture of a pressure containing part.

8.1.4 Do not exceed water temperature of 125°F (50°C) during the test.

8.1.5 Retain certification of the hydrostatic proof test by the manufacturer and make available upon request.

8.2 Hydrostatic Production Shell Test —Give steam traps/drains a hydrostatic shell test at a pressure of 1.5 times its maximum allowable pressure rating at 68°F (20°C).

8.2.1 Do not exceed water temperature of 125°F (50°C) during the hydrostatic test.

8.2.2 The minimum duration of the shell test shall be as follows:

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ through 2 (6-50 mm)</td>
<td>15 s</td>
</tr>
<tr>
<td>2½ through 8 (65-200 mm)</td>
<td>1 min</td>
</tr>
<tr>
<td>10 and over (250 mm)</td>
<td>3 min</td>
</tr>
</tbody>
</table>

8.2.2.1 Because of the complexity of product shape and size, the duration of the hydrostatic test may vary, but in no case shall this duration be less than that given in 8.2.2.

8.2.3 No visible leakage through pressure boundary walls or structural damage shall be evident during the shell tests.
8.3 Steam Production Shell Test—Test steam traps and drains no larger than 2-in. (50-mm) pipe size on saturated steam at their maximum operating pressure but not to exceed 250 psig (1820 kPa).

8.3.1 The minimum duration of the shell test shall be 15 s.

8.3.2 If this option is exercised, the manufacturer shall be able to certify that a prototype from each production lot of the same size steam trap/drain tested in this manner was subjected to a hydrostatic shell test in accordance with 8.2.

8.3.3 Show no visible leakage or structural damage during the shell tests.

8.4 Air Production Shell Test—Test traps and drains no larger than 2-in. (50-mm) pipe size for shell leaks on air at ambient temperature and 80 psi (551 kPa).

8.4.1 The minimum duration of the shell test shall be 15 s.

8.4.2 If this option is exercised, the manufacturer shall be able to certify that a prototype from each production lot of the same size steam trap/drain tested in this manner was subjected to a hydrostatic shell test in accordance with 8.2.

8.4.3 Visually detectable leakage through the pressure retaing walls is not acceptable.

8.5 Operational Check Steam Test—Feed the steam trap with steam and introduce condensate intermittently. When only steam is present, the steam trap shall close. On the introduction of condensate, the steam trap shall open (the time taken will vary as a function of the steam trap type). When the condensate has been discharged, the steam trap shall close again when steam enters the trap. The test is satisfied when at least one complete cycle has been performed.

8.6 Performance Characteristics Tests:

8.6.1 Determination of Minimum Operating Pressure—Carry out operational checks, as described in 8.5, while successively reducing the test pressure until the steam trap fails to open and close correctly. The minimum operating pressure is the lowest test pressure at which correct operation is observed.

8.6.2 Determination of Maximum Operating Pressure—Verify the maximum operating pressure of the steam trap by carrying out operational checks, as described in 8.5, while successively increasing the test pressure up to the steam trap’s maximum operating pressure. The steam trap shall open and close correctly throughout the test.

8.6.3 Determination of Maximum Operating Back Pressure—Carry out operational checks, as described in 8.5, with the outlet from the steam trap connected to a vessel in which the pressure can be raised, independent of the test pressure upstream of the steam trap. While maintaining a reference pressure at the steam trap inlet, successively raise the pressure at its outlet until the steam trap fails to open and close correctly. The maximum operating back pressure is the highest pressure applied to the steam trap outlet at which correct operation is still observed.

8.6.4 Determination of Air Venting Capability—Introduce air at a specified temperature into the trap or upstream piping. Check the air venting capability by an air flow measurement carried out at minimum and maximum operating pressure. Record the temperature at the trap inlet.

8.6.5 Determination of Operating Temperature—Feed steam into the steam trap to effect closure. Introduce condensate, at saturation steam temperature, and, unless the steam trap opens immediately, allow to cool slowly at the steam trap’s inlet. The operating temperature is the temperature of the condensate, measured at the inlet to the trap, at which the trap opens sufficiently to pass its specified capacity.

8.6.6 Determination of Condensate Capacity—Determine the capacity of the steam trap/drain by measuring the amount of condensate that is discharged from the device under specified conditions of pressure, pressure differential, and condensate temperature. Carry out the test with condensate at different temperatures and at different pressure within the steam trap/drain’s operating range in accordance with ANSI/ASME PTC 39.1.

8.6.7 Determination of Live Steam Loss—Use several methods to determine the amount of live steam lost, if any, by the steam trap/drain in accordance with ANSI/ASME PTC 39.1.

9. Product Marking

9.1 Each steam trap/drain shall as a minimum be permanently marked with the following information:

9.1.1 Manufacturer’s name or trademark.

9.1.2 Maximum operating pressure (PMO) or maximum differential pressure (ΔPMX) rating.

9.1.3 Maximum allowable pressure (PMA).

9.1.4 Indication of flow direction (arrow or word “inlet'' or “outlet,’’ or both).

9.1.5 ASTM designation of this specification.

9.2 Flanges, butt welding, threaded, or other ends complying with a standard listed in 5.2.1 may be marked in accordance with the applicable requirements of MSS SP-25 for dimensional identification purpose if desired.

9.3 Omission of Markings on Trap/Drain Body—On traps/drains whose size or shape limit the markings, markings shall be applied on an identification plate securely attached to the body. In no case shall the markings be hidden by the fixing elements of the steam trap.

9.4 Additional Markings—A manufacturer having complied with the requirements of Section 9 may include the following:

9.4.1 Mark any of the above mentioned items in more than one place, for example, if any item is marked on the body, it may also be repeated on an identification plate; or

9.4.2 Add any other markings, for example, catalog item numbers, providing that there is no risk of confusion between these markings and those mentioned in Section 9.

10. Quality Control

10.1 The trap/drain manufacturer shall maintain the quality of the traps/drain that are designed, tested, and marked in accordance with this specification. At no time shall a trap/drain be sold with this specification designation that does not meet the requirements herein.

11. Keywords

11.1 fluid discharge; steam drains; steam traps; valve
Standard Specification for Manhole Cover Assembly, Bolted, Semi-Flush, Oiltight and Watertight

This standard is issued under the fixed designation F 1142; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides design and construction criteria for a semi-flush, oiltight, and watertight bolted manhole cover assembly.

1.2 The manhole cover assembly depicted in this specification is for use in decks or bulkheads requiring oiltight and watertight covers that are not required to be completely flush. Manhole cover assemblies shall be complete with covers, mounting rings, gaskets, welded studs, washers, and nuts.

1.3 Handles, if required, shall be as specified in the ordering information.

1.4 The values stated in inch pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 This specification is not applicable to certain hazardous cargos (see Section 46 CFR 153.254 and 46 CFR 154.340).

1.6 This specification provides design and construction for manhole cover assemblies subjected to lateral pressures such as resulting from vehicle loads or hydrostatic pressures. Where manhole cover assemblies are subjected to primary or cyclic loads, other reinforcement or construction criteria may be necessary to integrate the manhole assembly with the required structural reinforcement for openings in decks or bulkheads. Design of the manhole cover assembly for primary or cyclic loads is beyond the scope of this specification.

2. Referenced Documents

2.1 ASTM Standards:
   - A 36/A 36M Specification for Structural Steel
   - A 131/A 131M Specification for Structural Steel for Ships
   - A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   - B 36/B 36M Specification for Brass Plate, Sheet, Strip, and Rolled Bar
   - D 2000 Classification System for Rubber Products in Automotive Applications
   - F 783 Specification for Staple, Handgrab, Handle, and Stirrup Rung

2.2 ANSI Standards:
   - B1.1 Unified Inch Screw Threads
   - B18.2.1 Square and Hex Bolts and Screws, Inch Series
   - Y14.5M Dimensioning and Tolerancing

2.3 American Bureau of Shipping Standard:
   - Rules for Building and Classing Steel Vessels

2.4 Steel Structures Painting Council Standard:
   - SP-10 Surface Preparation Specification No. 10

2.5 Code of Federal Regulations Standard:
   - CFR 46 Code of Federal Regulations

3. Terminology

3.1 Definitions:
   - manhole—an accessway located in a tank structure.
   - semi-flush—placement of the cover over the ringed opening (without coaming).

4. Classification

4.1 Type I—15-in. (381-mm) size of access opening. Type II—18-in. (457-mm) size of access opening.

4.2 Grade 1—1/2-in. (9.5-mm) thick cover plate. Grade 2—3/4-in. (12.7-mm) thick cover plate. Grade 3—1/2-in. (12.7-mm) thick cover plate.

4.3 Class A Manhole Cover Assemblies—Class A manhole cover assemblies shall be abrasive blasted to near white metal in accordance with SSPC SP-10, and a commercial marine quality, nonhazardous, corrosion-inhibiting, and oil-resistant
primer coating be applied for protection for a period of one year during shipping and in shipyard handling.

4.4 Class B Manhole Cover Assemblies—Class B manhole cover assemblies shall be galvanized in accordance with Specification A 153/A 153M.

5. Ordering Information

5.1 The purchasers ordering information shall include the following:

5.1.1 ASTM designation and year of issue,
5.1.2 Type (see 4.1),
5.1.3 Grade (see 4.2),
5.1.4 Class (see 4.3),
5.1.5 Quantity,
5.1.6 Remarks—Handles (are/are not) required,
5.1.7 Approval—Classification Society approval (is/is not) required, and
5.1.8 Gasket, if other than specified (see 6.6).

6. Materials and Manufacture

6.1 Plate for the cover and the ring shall be of Specifications A 36/A 36M or A 131/A 131M steel.
6.2 Round bar for the handle shall be in accordance with Specification F 783, Type A.
6.3 Welded studs shall be ¼-in. (19.05-mm) 10 UNC-2A by 1¼ in. (44.4 mm) long and manufactured of ordinary steel to commercial standards. Threads shall be the coarse thread series as specified in the latest issue of ANSI B1.1.
6.4 Washers shall be ANSI B18.2.1 Type A, ¼-in. (19.05-mm) washer, 2-in. (50.8-mm) by 0.148-in. (3.8-mm) thick standard flat manufactured of yellow brass, Specification B 36/B 36M.
6.5 Heavy hex nuts shall be ¼-in. (19.05-mm) 10 UNC-2B and manufactured of yellow brass, Specification B 36/B 36. Threads in nuts shall conform to the dimensions for coarse threads with tolerances prescribed in ANSI B1.1. The nuts shall conform to dimensions prescribed in ANSI B18.2.1.
6.6 Unless otherwise specified in ordering information, gasket shall be rubber, ⅛ in. (4.8 mm) thick, 50 ± 5 durometer prescribed per Classification D 2000 5BC507 A14 E034. Manhole cover assemblies for government application, see Annex A2 for type of gasket.
6.7 Welding shall conform to the latest issue of the American Bureau of Shipping rules or other classification society rules as may be applicable.
6.8 Details of bolted manhole cover assembly are shown in Fig. 1.

7. Dimensions

7.1 Dimensions of manhole cover assembly shall be as indicated in Table 1.
7.2 For plating up to and including ¼-in. (6.4-mm) thickness, use cover plate of ¼-in. (6.4-mm) thickness. Plating over ¼ in. (6.4 mm) up to, and including ⅛-in. (9.5-mm) thickness, use cover plate of ⅛-in. (9.5-mm) thickness. Plating over ⅛-in. (9.5-mm) thickness, use cover plate of ½-in. (12.7-mm) thickness.

8. Workmanship, Finish, and Appearance

8.1 Items produced under this specification shall be free of splinters, sharp edges, burrs, projections, and weld spatters.

9. Sampling

9.1 For orders for one or two manhole cover assemblies, each manhole cover assembly shall be inspected.
9.2 For orders for three to ten manhole cover assemblies, two manhole cover assemblies shall be selected at random. If any one of them fails to meet requirements, then all manholes in the order shall be inspected.
9.3 For orders for more than ten manhole cover assemblies, they shall be separated into groups of ten (or fraction thereof) for sampling purposes.

10. Inspection and Testing

10.1 Responsibility—Unless otherwise specified in the order, the manufacturer is responsible for the performance of all inspection and testing specified herein. The manufacturer may use his own facilities or any commercial facility acceptable to the purchaser. The purchaser reserves the right to perform any of the inspections and tests set forth where such are deemed necessary to assure that supplies conform to prescribed requirements. Nonconforming manhole cover assemblies shall not be offered for delivery.
10.2 Inspection—The dimensions of the manhole cover assembly and its components shall be checked to ensure that they are within specified tolerances.
10.3 Test Methods—Each manhole cover assembly shall be designed to the pressure listed in Table 1 and tested to a pressure equal to 1.5 times the design pressure. The test pressure shall be held for a minimum of 5 min. There shall be no visible sign of leakage, permanent deformation, or other indications of structural failure of the manhole cover assembly.
10.3.1 Before delivery, the manhole cover assemblies shall be certified as to their watertight and oiltight integrity. Groups of manhole cover assemblies whose representative samples pass the tightness test shall be certified for watertight and oiltight integrity to their design pressure.

11. Product Marking

11.1 Each manhole cover assembly shall be marked with the purchase order number, item number from purchase order, ASTM designation number, type, grade, class, and manufacturer’s name. Marking may be done by paint, stencil, or weatherproof tag.

12. Packaging and Package Marking

12.1 Unless otherwise specified, packaging shall conform to manufacturer’s normal commercial practice, and in such a manner that will ensure acceptance by common carrier and afford protection against physical damage during shipment. Shipping containers shall conform to carrier regulations as applicable to the mode of transportation.
12.2 For government procurements for long-term storage or overseas shipment, the requirements of Annex A1 apply. In such case, the required level of packaging shall be specified.
FIG. 1 Manhole Cover Assembly, Bolted, Semi-Flush, Oiltight and Watertight

NOTE 1—1 in. = 25.4 mm.
TABLE 1 Dimensions for Bolted, Semi-Flush, Oiltight and Watertight Manhole Cover Assembly

**Note:** 1 in. = 25.4 mm.

<table>
<thead>
<tr>
<th>Type</th>
<th>Grade</th>
<th>Plate Thickness</th>
<th>Overall Size</th>
<th>Deck Cut</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E, a</th>
<th>F, a</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>1/4 (6.5)</td>
<td>15 × 23 (381 × 584)</td>
<td>15</td>
<td>2</td>
<td>3/16 (86)</td>
<td>6/16 (171)</td>
<td>7</td>
<td>21</td>
<td>147</td>
<td>7/16 (191)</td>
<td>8</td>
<td>203</td>
<td>9/16 (235)</td>
<td>10/16 (267)</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>3/8 (9.5)</td>
<td>15 × 23 (381 × 584)</td>
<td>15</td>
<td>2</td>
<td>3/16 (86)</td>
<td>6/16 (171)</td>
<td>7</td>
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<td>147</td>
<td>7/16 (191)</td>
<td>8</td>
<td>203</td>
<td>9/16 (235)</td>
<td>10/16 (267)</td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td>1/2 (12.5)</td>
<td>15 × 23 (381 × 584)</td>
<td>15</td>
<td>2</td>
<td>3/16 (86)</td>
<td>6/16 (171)</td>
<td>7</td>
<td>21</td>
<td>147</td>
<td>7/16 (191)</td>
<td>8</td>
<td>203</td>
<td>9/16 (235)</td>
<td>10/16 (267)</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>1/4 (6.5)</td>
<td>18 × 24 (457 × 610)</td>
<td>18</td>
<td>2</td>
<td>3/16 (83)</td>
<td>6/16 (165)</td>
<td>8</td>
<td>18</td>
<td>144</td>
<td>9</td>
<td>229</td>
<td>9/16 (241)</td>
<td>10/16 (273)</td>
<td>12</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>3/8 (9.5)</td>
<td>18 × 24 (457 × 610)</td>
<td>18</td>
<td>2</td>
<td>3/16 (83)</td>
<td>6/16 (165)</td>
<td>8</td>
<td>21</td>
<td>144</td>
<td>9</td>
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<td>10/16 (273)</td>
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<tr>
<td>II</td>
<td>3</td>
<td>1/2 (12.5)</td>
<td>18 × 24 (457 × 610)</td>
<td>18</td>
<td>2</td>
<td>3/16 (83)</td>
<td>6/16 (165)</td>
<td>8</td>
<td>18</td>
<td>144</td>
<td>9</td>
<td>229</td>
<td>9/16 (241)</td>
<td>10/16 (273)</td>
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<table>
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<th>Design Pressure (kPa)</th>
<th>Design Pressure (lb)</th>
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<td>24</td>
<td>20.0</td>
<td>137.9</td>
<td>114</td>
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</tr>
<tr>
<td>24</td>
<td>35.6</td>
<td>245.5</td>
<td>140</td>
<td>64</td>
</tr>
</tbody>
</table>

a The letters in the headings designate the following:

- **A** = number of spaces on straight side,
- **B** = bolt spacing (straight side),
- **C** = total span,
- **D** = number of spaces on arc side,
- **E** = bolt spacing (arc side),
- **F** = arc span,
- **G** = accessway inner radius,
- **H** = seat and gasket inner radius,
- **I** = bolt circle arc radius,
- **J** = seat and gasket outer radius, and
- **K** = offset for radii from center of accessway and cover.
13. Keywords
13.1 bulkhead; decks; manhole cover assembly; marine technology; ships

ANNEXES
(Mandatory Information)

A1. PACKING FOR DoD PROCUREMENTS (GOVERNMENT APPLICATIONS)

A1.1 Referenced Documents (for this annex only)

A1.1.1 Federal Standards:
- PPP-B-576 Box, Wood, Cleated, Veneer, Paper Overlaid
- PPP-B-585 Boxes, Wood, Wirebound
- PPP-B-591 Boxes, Fiberboard, Wood-Cleated
- PPP-B-601 Boxes, Wood, Cleated—Plywood
- PPP-B-621 Boxes, Wood, Nailed and Lock Corner
- PPP-B-636 Box, Fiberboard
- PPP-B-640 Boxes, Fiberboard, Corrugated, Triple, Wall

A1.1.2 Military Standard:
- MIL-STD-129 Marking for Shipment and Storage

A1.1.3 Official Classification Committee Standard:
- Uniform Freight Classification Rules

A1.2 Packing—The manhole cover assembly shall be cushioned, blocked, or braced within the container in a manner to prohibit movement. Unless otherwise specified in the order, one manhole cover assembly shall be packed per container.

When more than one manhole cover assembly is required to be packed in each container, the gross mass of the wood or wood-cleated boxes shall not exceed approximately 100 kg.

A1.2.1 Level A
Manhole cover assembly shall be packed in containers conforming to any one of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification:</th>
<th>Type or Class:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 3</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 2</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>Weather Resistant</td>
</tr>
<tr>
<td>PPP-B-640</td>
<td>Class 2</td>
</tr>
</tbody>
</table>

A1.2.1.1 Boxes shall be closed and banded in accordance with the applicable box specification.

A1.2.2 Level B
Manhole cover assemblies shall be packed in boxes conforming to any of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification:</th>
<th>Type or Class:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576 PPPP0-B-585</td>
<td>Domestic Class 1 or 2</td>
</tr>
</tbody>
</table>

A2. DoD MANHOLE COVER ASSEMBLY SPECIAL APPLICATION

A2.1 Referenced Documents (for this annex only)

A2.1.1 Military Standards:
- MIL-C-6183 Cork and Rubber Composition Sheet for Aromatic Fuel and Oil Resistant Gaskets
- MIL-G-1149 Gasket Materials, Synthetic Rubber 50 and 65 Durometer Hardness
- MIL-R-900 Rubber Gasket Material, 45 Durometer Hardness
- MIL-R-83248 Rubber Fluorocarbon Elastomer, High Temperature, Fluid and Compression Set Resistant

A2.2 Gasket materials used in DoD manhole cover assemblies shall be as follows:

<table>
<thead>
<tr>
<th>Manhole Cover Assembly Service</th>
<th>Required Gasket Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>General service</td>
<td>MIL-R-900</td>
</tr>
<tr>
<td>Freshwater</td>
<td>MIL-G-1149, Class 2</td>
</tr>
<tr>
<td>Oil, gasoline, saltwater</td>
<td>MIL-C-6183, Class 1</td>
</tr>
<tr>
<td>Hydraulic machinery spaces using phosphate ester-based hydraulic fluid</td>
<td>MIL-R-83248</td>
</tr>
</tbody>
</table>

A2.3 DoD manhole covers shall be Class B.
Standard Specification for Manhole Cover Assembly, Bolted, Raised, Oiltight and Watertight

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting and Deck Machinery.


1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting and Deck Machinery.


1. Scope

1.1 This specification provides design and construction criteria for a raised, bolted, oiltight, and watertight manhole cover assembly.

1.2 The manhole cover assemblies depicted in this specification are for use in decks or bulkheads in which the manhole cover assemblies must be of the raised type. Manhole cover shall be complete with coaming, gasket, welded studs or bolts, washers, and nuts.

1.3 Determination of the use of handles will be as specified in the ordering information.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 This specification is not applicable to certain hazardous cargos (see Section 46 CFR 153.254 and 46 CFR 154.340).

1.6 This specification provides design and construction for manhole cover assemblies subjected to lateral pressures such as resulting from vehicle loads or hydrostatic pressures. Where manhole cover assemblies are subjected to primary or cyclic loads, other reinforcement or construction criteria may be necessary to integrate the manhole assembly with the required structural reinforcement for openings in decks or bulkheads. Design of the manhole cover assembly for primary or cyclic loads is beyond the scope of this specification.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Structural Steel
A 131/A 131M Specification for Structural Steel for Ships
A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
B 36/B 36M Specification for Brass Plate, Sheet, Strip, and Rolled Bar

D 2000 Classification System for Rubber Products in Automotive Applications
F 783 Specification for Staple, Handgrab, Handle, and Stirrup Rung

2.2 ANSI Standards:

B1.1 Unified Inch Screw Threads
ANSI Y14.5M Dimensioning and Tolerancing
B18.2.1 Square and Hex Bolts and Screws, Inch Series

2.3 American Bureau of Shipping Standard:

Rules for Building and Classing Steel Vessels

2.4 Steel Structures Painting Council Standard:

SP-10 Surface Preparation Specification No. 10

2.5 Code of Federal Regulations Standard:

CFR 46 Code of Federal Regulations

3. Terminology

3.1 Definitions:

3.1.1 manhole—an accessway located in a tank structure.

3.1.2 raised—manhole cover seat is located on an angle or flat bar coaming which protrudes from the tank structure into the space from which it is accessed.

4. Classification

4.1 Type I—15- by 23-in. (381- by 584-mm) size of access opening. Type II—18- by 24-in. (457- by 610-mm) size of access opening.

4.2 Grade 1—1/4-in. (6.35-mm) thick cover plate. Grade 2—3/8-in. (9.5-mm) thick cover plate. Grade 3—1/2-in. (13-mm) thick cover plate.

4.3 Class A Manhole Cover Assemblies—Class A manhole cover assemblies shall be abrasive blasted to near white metal in accordance with SSPC SP-10 and a commercial marine quality nonhazardous corrosion-inhibiting and oil-resistant primer coating be applied for protection for a period of one year during shipping and in shipyard handling.

5 Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

4.4 Class B Manhole Cover Assemblies—Class B manhole cover assemblies shall be galvanized in accordance with Specification A 153/A 153M.

5. Ordering Information

5.1 The purchasers’ ordering information shall include the following information:

5.1.1 ASTM designation and year of issue,
5.1.2 Type (see 4.1),
5.1.3 Grade (see 4.2),
5.1.4 Class (see 4.3 and 4.4),
5.1.5 Shape (rectangular or oval) (see Fig. 1 and Fig. 2),
5.1.6 Quantity,
5.1.7 Remarks—Handles (are/are not) required, and
5.1.8 Approval—Classification society approval (is/is not) required.

5.1.9 Gasket, if other than specified (see 6.7).

6. Materials and Manufacture

6.1 Plate for the cover to be of Specifications A 36/A 36M or A 131/A 131M steel.

6.2 Coaming to be of Specifications A 36/A 36M or A 131/A 131M steel.

6.3 Round bar for the handle shall be in accordance with Specification F 783, Type A.

6.4 Bolts shall be ¼ in. (19.05 mm) by 2 ¾ in. (57 mm) long. Welded studs shall be ¼ in. (19.05 mm) by 1 ¾ in. (44.4 mm) long. Bolts or welded studs shall be manufactured of ordinary steel to commercial standards. Threads shall be the coarse thread series as specified in the latest issue of ANSI B1.1.

6.5 Washers shall be ANSI B18.2.1 Type A, ¾-in. (19.05-mm) washer, 2-in. (50.8-mm) by 0.148-in. (3.8-mm) thick standard flat manufactured of yellow brass, Specification B 36/B 36M.

6.6 Heavy hex nuts shall be ¾ in. (19.05 mm) and manufactured of yellow brass, Specification B 36/B 36M. Threads in nuts shall conform to the dimensions for coarse threads with tolerances prescribed in ANSI B1.1. The nut shall conform to dimensions prescribed in ANSI B18.2.1.

6.7 Unless otherwise specified in ordering information, gasket shall be rubber, ⅝ in. (4.8 mm) thick, 50 ± 5 durometer, or other such classification society rules as may be applicable. Manhole cover assemblies for government application see Annex A2 for type of gaskets.

6.8 Welding to conform to the latest issue of the American Bureau of Shipping Rules per Classification D 2000 5BC507 A14 E034.

6.9 Details of bolted manhole cover assembly is shown in Fig. 1 and Fig. 2.

7. Dimensions and Permissible Variations

7.1 Dimensions of manhole assembly shall be as indicated in Table 1 and Table 2.

7.2 For plating up to and including ¼-in. (6.4-mm) thickness, use cover plate of ¼-in. (6.4-mm) thickness. Plating over ¼-in. (6.4-mm) up to, and including ⅜-in. (9.5-mm) thickness, use cover plate of ⅜-in. (9.5-mm) thickness. Plating over ⅜-in. (9.5-mm) up to, and including ½-in. (12.7-mm) thickness.

8. Workmanship, Finish, and Appearance

8.1 Items produced under this specification shall be free of splinters, sharp edges, burrs, projections, and weld spatters.

9. Sampling

9.1 For orders for one or two manhole cover assemblies, each manhole cover assembly shall be inspected.

9.2 For orders for three to ten manhole cover assemblies, two manhole cover assemblies shall be selected at random. If any one of them fails to meet requirements, then all manhole cover assemblies in the order shall be inspected.

9.3 For orders for more than ten manhole cover assemblies, they shall be separated into groups of ten (or fraction thereof) for sampling purposes.

10. Inspection and Testing

10.1 Responsibility—Unless otherwise in the order, the manufacturer is responsible for the performance of all inspection and testing specified herein. The manufacturer may use his own facilities or any commercial facility acceptable to the purchaser. The purchaser reserves the right to perform any of the inspections and tests set forth where such are deemed necessary to assure that supplies conform to prescribed requirements. Nonconforming manhole cover assemblies shall not be offered for delivery.

10.2 Inspection—The dimensions of the manhole cover assembly and its components shall be checked to ensure that they are within specified tolerances.

10.3 Test Method—Each manhole cover assembly shall be designed to the pressure listed in Table 1 and Table 2 and tested to a pressure equal to 1.5 times the design pressure. The test pressure shall be held for a minimum of 5 min. There shall be no visible sign of leakage, permanent deformation, or other indications of structural failure of the manhole cover assembly.

10.3.1 Before delivery, the manhole cover assemblies shall be certified as to their watertight and oiltight integrity. Groups of manhole cover assemblies whose representative samples pass the tightness test shall be certified for watertight and oiltight integrity to their design pressure.

11. Product Marking

11.1 Each manhole cover assembly shall be marked with the purchase order number. Item number from purchase order, ASTM designation number, type, grade, class, and manufacturer’s name. Marking may be by paint, stencil, or weatherproof tag.

12. Packaging and Package Marking

12.1 Unless otherwise specified, packaging shall conform to the manufacturer’s normal commercial practice, and in such a manner that will ensure acceptance by common carrier and afford protection against physical damage during shipment. Shipping containers shall conform to carrier regulations as applicable to the mode of transportation.
Note 1—See Table 1 for manhole cover assembly dimensions.
1 in. = 25.4 mm.

FIG. 1 Rectangular Manhole Cover Assembly, Raised, Bolted, Oiltight and Watertight

13. Keywords

13.1 bulkhead; decks; manhole cover; manhole cover assembly; marine technology; ships
FIG. 2 Oval Manhole Cover Assembly, Raised, Bolted, Oiltight and Watertight

Note 1—See Table 2 for manhole cover assembly dimensions.

1 in. = 25.4 mm.
### TABLE 1 Dimensions for Rectangle, Raised, Oiltight and Watertight Manhole Cover Assembly

**NOTE 1—1 in. = 25.4 mm.**

| Type | Grade | Plate Thickness | Deck Cut Overall Size | A | B | C | D | E | F | G | H | I | J |
|------|-------|----------------|-----------------------|---|---|---|---|---|---|---|---|---|---|---|
|      |       |                | in. (mm) in. (mm)     | in. (mm) | in. (mm) | in. (mm) | in. (mm) | in. (mm) | in. (mm) | in. (mm) | in. (mm) | in. (mm) | in. (mm) |
| I 1  | ⅛ (6.5)| 15 × 23 (381 × 584) | 7 | 3 | 76 | 21 | 533 | 3 ⅛ (79) | 4 | 3 ⅝ (81) | 12 ⅛ (324) | 3 ¼ (83) | 30 ½ (781) | 22 ⅛ (578) |
| I 2  | ⅛ (6.5)| 15 × 23 (381 × 584) | 7 | 3 | 76 | 21 | 533 | 3 ⅛ (79) | 4 | 3 ⅝ (81) | 12 ⅛ (324) | 3 ¼ (83) | 30 ½ (781) | 22 ⅛ (578) |
| I 3  | ⅛ (6.5)| 15 × 23 (381 × 584) | 7 | 3 | 76 | 21 | 533 | 3 ⅛ (79) | 4 | 3 ⅝ (81) | 12 ⅛ (324) | 3 ¼ (83) | 30 ½ (781) | 22 ⅛ (578) |
| II 1 | ⅛ (6.5)| 18 × 24 (457 × 610) | 7 | 3 ⅛ (79) | 21 ⅛ (556) | 3 ⅛ (81) | 5 | 3 ¼ (83) | 16 ⅞ (413) | 3 | 76 | 31 ½ (806) | 25 ¼ (654) |
| II 2 | ⅛ (6.5)| 18 × 24 (457 × 610) | 7 | 3 ⅛ (79) | 21 ⅛ (556) | 3 ⅛ (81) | 5 | 3 ¼ (83) | 16 ⅞ (413) | 3 | 76 | 31 ½ (806) | 25 ¼ (654) |
| II 3 | ⅛ (6.5)| 18 × 24 (457 × 610) | 7 | 3 ⅛ (79) | 21 ⅛ (556) | 3 ⅛ (81) | 5 | 3 ¼ (83) | 16 ⅞ (413) | 3 | 76 | 31 ½ (806) | 25 ¼ (654) |

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<tr>
<th>K</th>
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<td>(191)</td>
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</tr>
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<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of spaces on long side,</td>
<td>bolt spacing (long side),</td>
<td>total span,</td>
<td>corner bolt distance from long side end bolt,</td>
<td>number of spaces on short side,</td>
<td>bolt spacing (short side),</td>
<td>total span,</td>
<td>corner bolt distance from short side end bolt,</td>
<td>coaming long side span,</td>
<td>coaming short side span,</td>
</tr>
</tbody>
</table>

K = accessway inner radius,
L = offset for radii from center of accessway and cover,
M = short side gasket inner edge distance from cover centerline, and
N = long side gasket inner edge distance from cover centerline.

* The letters in the headings designate the following:
### TABLE 2  Dimensions for Oval, Raised, Oiltight and Watertight Manhole Cover AssemblyaN

**NOTE 1—1 in. = 25.4 mm.**

<table>
<thead>
<tr>
<th>Type</th>
<th>Grade</th>
<th>Plate Thickness</th>
<th>Overall Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E, a</th>
<th>F, a</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>1/4 (6.5)</td>
<td>15 x 23</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>3/8 (9.5)</td>
<td>15 x 23</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td>1/2 (12.5)</td>
<td>15 x 23</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>1/4 (6.5)</td>
<td>18 x 24</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>3/8 (9.5)</td>
<td>18 x 24</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>1/2 (12.5)</td>
<td>18 x 24</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stud</th>
<th>Quantity</th>
<th>Design Pressure</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>psi</td>
<td>lb</td>
</tr>
<tr>
<td>24</td>
<td>1.0</td>
<td>82.7</td>
<td>78</td>
</tr>
<tr>
<td>24</td>
<td>2.0</td>
<td>186.2</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>3.0</td>
<td>330.2</td>
<td>121</td>
</tr>
<tr>
<td>26</td>
<td>4.0</td>
<td>62.1</td>
<td>88</td>
</tr>
<tr>
<td>26</td>
<td>5.0</td>
<td>137.9</td>
<td>114</td>
</tr>
<tr>
<td>26</td>
<td>6.0</td>
<td>245.5</td>
<td>140</td>
</tr>
</tbody>
</table>

a The letters in the headings designate the following:

\[ A = \text{number of spaces on straight side,} \]
\[ B = \text{bolt spacing (straight side),} \]
\[ C = \text{total span,} \]
\[ D = \text{number of spaces on arc side,} \]
\[ E = \text{bolt spacing (arc side),} \]
\[ F = \text{arc span,} \]
\[ G = \text{accessway inner radius,} \]
\[ H = \text{seat and gasket inner radius,} \]
\[ I = \text{bolt circle arc radius,} \]
\[ J = \text{seat and gasket outer radius, and} \]
\[ K = \text{offset for radii from center of accessway and cover.} \]
ANNEXES

(Mandatory Information)

A1. PACKING FOR DoD PROCUREMENTS (GOVERNMENT APPLICATION)

A1.1 Referenced Documents (for this annex only)

A1.1.1 Federal Standards:
- PPP-B-576 Box, Wood, Cleated, Veneer, Paper Overlaid\(^7\)
- PPP-B-585 Boxes, Wood, Wirebound\(^7\)
- PPP-B-591 Boxes, Fiberboard, Wood-Cleated\(^7\)
- PPP-B-601 Boxes, Wood, Cleated—Plywood\(^7\)
- PPP-B-621 Boxes, Wood, Nailed and Lock Corner\(^7\)
- PPP-B-636 Box, Fiberboard\(^7\)
- PPP-B-640 Boxes, Fiberboard, Corrugated, Triple, Wall\(^7\)

A1.1.2 Military Standards:
- MIL-STD-129 Marking for Shipment and Storage\(^4\)

A1.1.3 Official Classification Committee Standard:
- Uniform Freight Classification Rules\(^8\)

A1.2 Packing—The manhole cover assembly shall be cushioned, blocked, or braced within the container in a manner to prohibit movement. Unless otherwise specified in the order, one manhole cover assembly shall be packed per container. When more than one manhole cover assembly is required to be packed in each container, the gross mass of the wood or wood-cleated boxes shall not exceed approximately 100 kg.

A1.2.1 Level A—Manhole cover assembly shall be packed in containers conforming to any one of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification:</th>
<th>Type or Class:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 3</td>
</tr>
</tbody>
</table>

A1.2.1.1 Boxes shall be closed and banded in accordance with the applicable box specification.

A1.2.2 Level B—Manhole cover assemblies shall be packed in boxes conforming to any of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification:</th>
<th>Type or Class:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 1 or 2</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 1</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-640</td>
<td>Class 1</td>
</tr>
</tbody>
</table>

A1.2.2.1 Box closures shall be as specified in the applicable box specification. The gross mass of wood or wood-cleated boxes shall not exceed 100 kg.

A1.2.3 Level C—Packing shall be accomplished in a manner that will ensure acceptance by common carrier, at lowest rate, and will afford protection against physical or mechanical damage during direct shipment from the supply source to the using activity for early installation. The shipping containers or method of packing shall conform to the Uniform Freight Classification Rules and Regulations or other carrier regulations as applicable to the mode of transportation and may conform to the manufacturer’s commercial practice.

A1.3 Marking—In addition to any special marking required by the order, shipment shall be marked in accordance with MIL-STD-129.

A2. DoD MANHOLE COVER ASSEMBLY—SPECIAL APPLICATION

A2.1 Referenced Documents (for this annex only)

A2.1.1 Military Standards:
- MIL-C-6183 Cork and Rubber Composition Sheet for Aromatic Fuel and Oil Resistant Gaskets\(^7\)
- MIL-G-1149 Gasket Materials, Synthetic Rubber 50 and 65 Durometer Hardness\(^7\)
- MIL-R-900 Rubber Gasket Material as Durometer Hardness\(^7\)
- MIL-R-83248 Rubber Fluorocarbon Elastomer, High Temperature, Fluid and Compression Set Resistant\(^7\)

A2.2 Gasket materials used in DoD manhole cover assemblies shall be as follows:

<table>
<thead>
<tr>
<th>Manhole Cover Assembly Service:</th>
<th>Required Gasket Material:</th>
</tr>
</thead>
<tbody>
<tr>
<td>General service</td>
<td>MIL-R-900</td>
</tr>
<tr>
<td>Fresh water</td>
<td>MIL-G-1149, Class 2</td>
</tr>
<tr>
<td>Oil, gasoline, saltwater</td>
<td>MIL-C-6183, Class 1</td>
</tr>
<tr>
<td>Hydraulic machinery spaces using phosphate ester-based hydraulic fluid</td>
<td>MIL-R-83248</td>
</tr>
</tbody>
</table>

A2.3 DoD manhole covers shall be Class B.
1. Scope

1.1 This specification provides design and construction criteria for a semi-flush, oiltight and watertight bolted hinged manhole cover assembly.

1.2 The manhole cover assemblies depicted on this specification are for use in decks or bulkheads requiring oiltight and watertight covers that are not required to be completely flush. Manhole cover assemblies shall be complete with covers, mounting rings, gaskets, studs, washers, hinge assemblies, and nuts.

1.3 Handles, if required, shall be as specified in the ordering information.

1.4 Values stated in inch-pound units are to be regarded as standard.

1.5 This standard is not applicable to certain hazardous cargos. (See 46CFR 153.254 and 46CFR 154.340.)

1.6 This specification provides design and construction for manhole cover assemblies subjected to lateral pressures such as resulting from vehicle loads or hydrostatic pressures. Where manhole cover assemblies are subjected to primary or cyclic loads, other reinforcement or construction criteria may be necessary to integrate the manhole assembly with the required structural reinforcement for openings in decks or bulkheads. Design of the manhole cover assembly for primary or cyclic loads is beyond the scope of this specification.

2. Referenced Documents

2.1 ASTM Standards:
- A 36/A 36M Specification for Structural Steel
- A 131/A 131M Specification for Structural Steel for Ships
- A 153/A 153M Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware
- A 575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
- B 36/B 36M Specification for Brass Plate, Sheet, Strip, and Rolled Bar
- D 2000 Classification System for Rubber Products in Automotive Applications
- F 783 Specification for Staple, Handgrab, Handle, and Stirrup Rung

2.2 ANSI Standards:
- B1.1 Unified Inch Screw Threads
- Y14.5M Dimensioning and Tolerancing
- B18.2.1 Square and Hex Bolts and Screws, Inch Series

2.3 ABS Standard:
- Rules for Building and Classing Steel Vessels

2.4 Steel Structures Painting Council Standard:
- SP-10 Surface Preparation Specification No. 10
- 2.5 Code of Federal Regulations Standard:
- CFR 46 Code of Federal Regulations

3. Terminology

3.1 Definitions:
3.1.1 manhole—accessway located in a tank structure.
3.1.2 semi-flush—refers to the placement of the hinged plate over the ringed opening (without coaming).

4. Classification

4.1 Type I—15- by 23-in. (381- by 584-mm) size of access opening
4.2 Type II—18- by 24-in. (457- by 610-mm) size of access opening
4.3 Grade 1—⅛-in. (6.4-mm) thick cover plate
4.4 Grade 2—⅜-in. (9.5-mm) thick cover plate

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2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.


4 Available from American Bureau of Shipping (ABS), ABS Plaza, 16855 Northchase Dr., Houston, TX 77060.

5 Available from Steel Structures Painting Council (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656.

4.5 Grade 3—½-in. (12.7-mm) thick cover plate
4.6 Class A Manhole Cover Assemblies—Shall be abrasive blasted to near white metal in accordance with SSPC SP-10 and a commercial marine quality nonhazardous corrosion-inhibiting and oil-resistant primer coating be applied for protection for a period of one year during shipping and in shipyard handling.

4.7 Class B Manhole Cover Assemblies—Shall be galvanized in accordance with Specification A 153.

5. Ordering Information

5.1 The purchasers ordering information shall include the following:

5.1.1 ASTM designation and date.
5.1.2 Type (see 4.1 and 4.2).
5.1.3 Grade (see 4.3, 4.4, and 4.5).
5.1.4 Class see (4.6 and 4.7).
5.1.5 Quantity.
5.1.6 Remarks—Handles (are/are not) required.
5.1.7 Approval—Classification society approval (is/is not) required.
5.1.8 Gasket, if other than specified (see 6.8).

6. Materials and Manufacture

6.1 Plate for the cover, ring, hinge pad and hinge blade shall be in accordance with Specification A 36/A 36M or A 131/A 131M steel.
6.2 Round bar for the handle shall be in accordance with Specification F 783, Type A.
6.3 Round bar for the hinge pin shall be of Specification A 575 steel.
6.4 Welded studs shall be ¾ in. (19.1 mm)—10 UNC-2A by 1¾ in. (44.5 mm) long and manufactured of ordinary steel to commercial standards. Threads shall be the coarse thread series in accordance with the latest issue of ANSI B1.1.
6.5 Washers shall be ANSI B18.2.1 Type A, ¾-in. (19.1-mm) washer, 2-in. (50.8-mm) by 0.148-in. (3.8-mm) thick standard flat manufactured of yellow brass, in accordance with Specification B 36/B 36M.
6.6 Heavy hex nuts shall be ¾ in. (19.1 mm)—10 UNC-2B and manufactured of yellow brass, in accordance with Specification B 36/B 36M. Threads in nuts shall conform to the dimensions for coarse threads with tolerances prescribed in accordance with ANSI B1.1. The nuts shall conform to dimensions prescribed in accordance with ANSI B18.2.1.
6.7 Cotter pin to be in accordance with Specification B 36/B 36M yellow brass, ½ by 1¾ in. (3.2 by 44.5 mm) long.

6.8 Unless otherwise specified in ordering information, gasket to be rubber, ¾ in. (4.8 mm) thick, 50 ± 5 durometers per Classification D 2000 5BC07 A14 E034. For manhole cover assemblies for government application, see Annex A2 for type of gasket.
6.9 Welding to conform to the latest issue of American Bureau of Shipping Rules or other such classification society rules as may be applicable.
6.10 Details of bolted manholes are shown in Fig. 1.

7. Dimensions

7.1 Dimensions of manhole shall be as indicated in Table 1.
manner that will ensure acceptance by common carrier and afford protection against physical damage during shipment.

Shipping containers shall conform to carrier regulations as applicable to the mode of transportation.

**FIG. 1 Manhole Cover Assembly, Bolted, Hinged, Semi-Flush, Oiltight and Watertight.**
12.2 For government procurements for long-term storage or overseas shipment, the requirements of Annex A1 apply. In such case, the required level of packaging shall be specified.

13. Keywords

13.1 bulkhead; decks; manhole cover; manhole cover assembly; marine technology; ships
### TABLE 1 Dimensions for Bolted, Hinged, Semi-Flush, Oiltight and Watertight Manhole Cover Assembly

**NOTE 1—1 in. = 25.4 mm.**

| Type | Grade | Plate Thickness | Deck Cut Overall Size | A | B | C | D | E | F | G | H | I | J | K |
|------|-------|-----------------|-----------------------|---|---|---|---|---|---|---|---|---|---|---|---|
| I    | 1     | ⅛ (6.5)        | 15 × 23 (381 × 584)   | 2 | 3⅛ (86) | 6⅛ (171) | 7 | 21 | 147 | 7⅛ (191) | 8 | 203 | 9¼ (235) | 10½ (267) | 4 | (102) |
| I    | 2     | ⅜ (9.5)        | 15 × 23 (381 × 584)   | 2 | 3⅛ (86) | 6⅛ (171) | 7 | 21 | 147 | 7⅛ (191) | 8 | 203 | 9¼ (235) | 10½ (267) | 4 | (102) |
| I    | 3     | ⅜ (12.5)       | 15 × 23 (381 × 584)   | 2 | 3⅛ (86) | 6⅛ (171) | 7 | 21 | 147 | 7⅛ (191) | 8 | 203 | 9¼ (235) | 10½ (267) | 4 | (102) |
| II   | 1     | ⅛ (6.5)        | 18 × 24 (457 × 610)   | 2 | 3¼ (83) | 6⅛ (165) | 8 | 18 | 144 | 9 (229) | 9⅛ (241) | 10¼ (273) | 12 (305) | 3 | (76) |
| II   | 2     | ⅜ (9.5)        | 18 × 24 (457 × 610)   | 2 | 3¼ (83) | 6⅛ (165) | 8 | 18 | 144 | 9 (229) | 9⅛ (241) | 10¼ (273) | 12 (305) | 3 | (76) |
| II   | 3     | ⅜ (12.5)       | 18 × 24 (457 × 610)   | 2 | 3¼ (83) | 6⅛ (165) | 8 | 18 | 144 | 9 (229) | 9⅛ (241) | 10¼ (273) | 12 (305) | 3 | (76) |

<table>
<thead>
<tr>
<th>L</th>
<th>M</th>
<th>Stud Quantity</th>
<th>Design Pressure</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>psi</td>
<td>kPa</td>
</tr>
<tr>
<td>5</td>
<td>(127)</td>
<td>5⅛ (143)</td>
<td>22</td>
<td>12.0</td>
</tr>
<tr>
<td>5</td>
<td>(127)</td>
<td>5⅛ (143)</td>
<td>22</td>
<td>27.0</td>
</tr>
<tr>
<td>5</td>
<td>(127)</td>
<td>5⅛ (143)</td>
<td>22</td>
<td>47.9</td>
</tr>
<tr>
<td>5</td>
<td>(127)</td>
<td>5⅛ (143)</td>
<td>24</td>
<td>8.9</td>
</tr>
<tr>
<td>5</td>
<td>(127)</td>
<td>5⅛ (143)</td>
<td>24</td>
<td>20.0</td>
</tr>
<tr>
<td>5</td>
<td>(127)</td>
<td>5⅛ (143)</td>
<td>24</td>
<td>35.6</td>
</tr>
</tbody>
</table>

A The letters in the headings designate the following:

A = number of spaces on straight side,

B = bolt spacing (straight side),

C = total span,

D = number of spaces on arc side,

E = bolt spacing (arc side),

F = arc span,

G = accessway inner radius,

H = seat and gasket inner radius,

I = bolt circle arc radius,

J = seat and gasket outer radius,

K = offset for radii from center of accessway and cover,

L = distance from centerline of cover to centerline of hinge blade, and

M = distance from centerline of cover to centerline of hinge pad.
A1. PACKING FOR DoD PROCUREMENTS

A1.1 Referenced Documents

A1.1.1 Federal Specifications:
- PPP-B-576—Box, wood, cleated, veneer, paper overlaid.
- PPP-B-585—Boxes, wood, wirebound.
- PPP-B-591—Boxes, fiberboard, wood-cleated.
- PPP-B-601—Boxes, wood, cleated-plywood.
- PPP-B-621—Boxes, wood, nailed and lock corner.
- PPP-B-636—Box, fiberboard.
- PPP-B-640—Boxes, fiberboard, corrugated, triple, wall.

A1.1.2 Military Standard:
- MIL-STD-129—Marking for shipment and storage

A1.1.3 Official Classification Committee Rules:
- Uniform Freight Classification Rules

A1.2 Preservation

A1.2.1 None required.

A1.3 Packing

A1.3.1 The manhole cover assembly shall be cushioned, blocked, or braced within the container in a manner to prohibit movement. Unless otherwise specified in the order, one manhole cover assembly shall be packed per container. When more than one manhole cover assembly is required to be packed in each container, the gross mass of the wood or wood-cleated boxes shall not exceed approximately 100 kg.

A1.3.2 Level A

Manhole cover assembly shall be packed in containers conforming to any of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 3</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Overseas</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 2</td>
</tr>
</tbody>
</table>

Box closures shall be as specified in the applicable box specification. The gross mass of wood or wood-cleated boxes shall not exceed 100 kg.

A1.3.3 Level B

Manhole cover assemblies shall be packed in boxes conforming to any of the following specifications at the option of the manufacturer:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-576</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-585</td>
<td>Class 1 or 2</td>
</tr>
<tr>
<td>PPP-B-591</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-601</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>Class 1</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>Domestic</td>
</tr>
<tr>
<td>PPP-B-640</td>
<td>Class 1</td>
</tr>
</tbody>
</table>

A1.3.4 Level C

Packing shall be accomplished in a manner that will ensure acceptance by common carrier, at lowest rate, and will afford protection against physical or mechanical damage during direct shipment from the supply source to the using activity for early installation. The shipping containers or method of packing shall conform to the uniform freight classification rules and regulations or other carrier regulations as applicable to the mode of transportation and may conform to the manufacturer’s commercial practice.

A1.4 Marking

A1.4.1 In addition to any special marking required by the order, shipment shall be marked in accordance with MIL-STD-129.

A2. DoD MANHOLE COVER ASSEMBLY SPECIAL APPLICATION

A2.1 Referenced Documents (for this annex only)

A2.1.1 Military Standards:
- MIL-C-6183 Cork and Rubber Composition Sheet for Aromatic Fuel and Oil Resistant Gaskets

MIL-G-1149 Gasket Materials, Synthetic Rubber 50 and 65 Durometer Hardness
MIL-R-900 Rubber Gasket Material 45 Durometer Hardness
MIL-R-83248 Rubber Fluorocarbon Elastomer, High Temperature, Fluid and Compression Set Resistant

7 Available from Standardization Documents, Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
A2.2 Gasket materials used in DoD manhole cover assemblies shall be as follows:

<table>
<thead>
<tr>
<th>Manhole Cover Assembly Service</th>
<th>Required Gasket Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>General service</td>
<td>MIL-R-900</td>
</tr>
<tr>
<td>Fresh water</td>
<td>MIL-G-1149, Class 2</td>
</tr>
<tr>
<td>Oil, gasoline, saltwater</td>
<td>MIL-C-6183, Class 1</td>
</tr>
</tbody>
</table>

Manhole Cover Assembly Service:
- Hydraulic machinery spaces using phosphate ester-based hydraulic fluid
- MIL-R-83248

A2.2 DoD manhole covers shall be Class B.
Designation: F 1145 – 92 (Reapproved 2001)

An American National Standard

Standard Specification for
Turnbuckles, Swaged, Welded, Forged

This standard is issued under the fixed designation F 1145; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers swaged welded, cast, or forged turnbuckles with and without jam nuts.

1.2 A turnbuckle is an internally threaded loop or sleeve intended for assembly with a threaded stud, eye, hook, or jaw at each end, used for applying tension to rods, wire rope, etc.

1.3 The values stated in inch-pound units are to be regarded as standard. The SI units given in parentheses are for information purposes only and may be approximate.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 29 Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for
A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
D 3951 Practice for Commercial Packaging
2.2 AWS Standards:
A5.1 Covered Carbon Steel Arc Welding Electrodes
A5.2 Iron and Steel Oxyfuel Gas Welding Rods
A5.5 Low Alloy Steel Covered Arc Welding Electrodes
2.3 ANSI Standards:
B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)

B18.2.2 Square and Hex Nuts
2.4 Military Standards:
MIL-STD-1186 Cushioning, Anchoring, Bracing, Blocking, and Waterproofing; with Appropriate Test Methods
MIL-STD-2073-1 DoD Material Procedures for Development and Application of Packaging Requirements
2.5 Military Specification:
MIL-P-116 Preservation, Methods of
MIL-L-19140 Lumber and Plywood, Fire-Retardant Treated
2.6 Federal Specifications:
PPP-B-636 Boxes, Shipping, Fiberboard
PPP-F-320 Fiberboard: Corrugated and Solid Sheet Stock (Container Grade) and Cut Shapes
2.7 Federal Standard:
FED-STD-123 Marking for Shipment (Civil Agencies)

3. Classification

3.1 Turnbuckles covered under this specification shall be of the following types and grades, as specified (see 4.1.3 and 4.1.7):

3.1.1 Type I—Open turnbuckle bodies (see 5.2.4–5.2.7)
Grade
1 Forged
2 Spread
3 Resistance welded
4 Arc or gas welded
3.1.2 Type II—Pipe turnbuckle bodies (see 5.2.8).
3.1.3 Type III—Rigging turnbuckle bodies (see 5.2.9).
3.2 Turnbuckles covered under this specification shall be of the following classes and sizes, as specified (see 4.1.3):

3.2.1 Classes:
A—turnbuckle, body only without end pulls, heads not drilled.
B—turnbuckle, body only without end pulls, heads threaded right and left hand.
C—turnbuckle with stub and stub end pulls, complete.
D—turnbuckle with eye and eye end pulls, complete.
E—turnbuckle with hook and hook end pulls, complete.
F—turnbuckle with hook and eye end pulls, complete.
G—turnbuckle with jaw and jaw end pulls, complete.

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1 This specification is under the jurisdiction of ASTM Committee F25 on Shipbuilding and is the direct responsibility of Subcommittee F25.07 on General Requirements.
2 Annual Book of ASTM Standards, Vol 01.05.
3 Annual Book of ASTM Standards, Vol 01.06.
4 Annual Book of ASTM Standards, Vol 02.05.
6 Available from American Welding Society, 550 NW LeJeune Road, Miami, FL 33126.
7 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.
8 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
H—turnbuckle with jaw and eye end pulls, complete.

3.2.1.1 The arrangement of turnbuckle bodies and end pulls for Classes C, D, E, F, G, and H shall be similar to Fig. 1.

3.2.2 Sizes—Shall be as listed in Table 1 and Table 2.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 ASTM designation and year of issue,
4.1.2 Quantity required,
4.1.3 Type, class, and size (see 3.1, 3.2, and 8.1),
4.1.4 Material, if different (see 5.1.1),
4.1.5 Type thread required (see 7.3),
4.1.6 Type finish required (see 9.3),
4.1.7 Grade required, if Type I is specified (see 3.1.1),
4.1.8 Optional requirements, if any (see S1 and S2).

5. Materials and Manufacture

5.1 Materials:

5.1.1 Unless otherwise specified (see 4.1.4), turnbuckle and end pulls shall be made from steel of a grade which will meet the requirements of Table 3.

5.1.2 For materials used for welded turnbuckle bodies, eye and jaw end pulls, the carbon shall be 0.25 % maximum, sulfur 0.05 % maximum, and phosphorus 0.05 % maximum.

5.2 Manufacture:

5.2.1 Eye End Pulls—Eye end pulls shall be forged, resistance welded, or arc or gas welded, at the option of the
producer, except that when forged bodies are specified, forged-eye end pulls shall be required.

5.2.1.1 Each forged-eye end pull shall be forged at elevated temperature to final shape and size and shall be similar to Fig. 2. The shape of the eye may be either oval or round.

5.2.1.2 Resistance-welded eye end pulls shall be similar to Fig. 3. They shall be fabricated from one piece of material by bending the material to form the eye and joined by resistance welding process.

5.2.1.3 Arc- or gas-welded eye end pulls shall be similar to Fig. 4. They shall be fabricated from one piece of material by bending the material to form the eye and joined by welding. The cross-sectional area through the weld shall be not less than the cross-sectional area of the bar.

5.2.2 Jaw End Pulls—Jaw end pulls shall be forged, arc or gas welded, or upset, at the option of the producer, except that if forged bodies are specified, forged-jaw end pulls shall be provided.
5.2.2.1 Forged-jaw end pulls shall be similar to Fig. 5.

5.2.2.2 Arc- or gas-welded end pulls shall be similar to Fig. 6.

5.2.2.3 Upset jaw end pulls shall be similar to Fig. 7.

5.2.3 Hook End Pulls—Hook end pulls shall be forged and be similar to Fig. 8.

5.2.4 Type I, Grade 1 Turnbuckles—Each forged turnbuckle body shall be forged at elevated temperature to final shape and size and shall be similar to Fig. 9. The shape of the head of the turnbuckle shall be either round or hexagonal.

5.2.5 Type I, Grade 2 Turnbuckles—For each spread turnbuckle body, one piece of material shall be cut lengthwise from near one end to the other end by any suitable means, such as an oxyacetylene cutting torch; the resulting reins shall then be spread apart at elevated temperatures to final shape and size. The bodies shall be similar to Fig. 10. The shape of the cross section of the material shall be at the option of the producer.

5.2.6 Type I, Grade 3 Turnbuckles—Each resistance-welded turnbuckle body shall be fabricated by joining two formed pieces of material by either the flash or upset welding process. The welds shall be parallel to the long axis of the piece. The surfaces to be joined shall be held in intimate contact by external forces, an electric current passed through the surfaces, and the weld consolidated by the forces. The bodies shall be similar to Fig. 11. The shape of the cross section of the pieces shall be at the option of the producer.

5.2.7 Type I, Grade 4 Turnbuckles—The welds shall be either electric arc or oxyacetylene (gas) at the option of the producer. Arc- or gas-welded turnbuckle bodies shall be fabricated by joining four pieces of material by welds similar to Fig. 12. The faces of the welds shall not be concave but may be somewhat convex.

5.2.8 Type II, Pipe—Pipe turnbuckle bodies shall be forged, swaged, spun, drawn, or upset in way of the threaded ends, and shall be similar to Fig. 13.

5.2.9 Type III, Rigging—Rigging turnbuckle bodies shall be forged, similar to Fig. 14, and shall be provided with a heavy jam nut (see 5.1.3) of a type which does not depend upon deformation of the threads for security.

6. Mechanical Properties

6.1 The breaking strength of turnbuckles, equipped with end pulls, shall be not less than the value given in Table 3 for the required size, type, and grade of end pull specified.

6.2 End pulls shall be capable of bending through an angle of 90° around a pin twice the nominal major diameter of the end pull without either crack or rupture.
6.3 End pulls for Classes D, E, F, G, and H shall be capable of supporting a load equal to one half of the specified breaking strength without permanent deformation.

7. Other Requirements

7.1 All arc-welded bodies, eyes, and jaws shall be welded with Type 7015, 7016, 8015, or 8016 electrodes of AWS A 5.1 or AWS A 5.5, as applicable.

7.2 All gas-welded bodies, eyes, and jaws shall be welded with welding rods in accordance with AWS A 5.2.

7.3 Turnbuckle bodies and end pulls shall be threaded after fabrication to final size and shape. The threads in the heads of the turnbuckle bodies and on the end pulls shall comply with ANSI B 1.1 (see 4.1.5). Unified threads in the coarse (UNC) and fine (UNF) standard series should be used. If neither is specified, the threads will be in the UNC series. If the standard diameter-pitch combinations are not suitable, the UNS threads with dimensions in accordance with ANSI B 1.1 should be used.

7.3.1 Threads on the finished turnbuckle shall not be looser than class 1A/1B fit. If coated turnbuckles are specified, the male threads on the end pulls may be undercut, as necessary, so that after coating they will properly mate (not looser than 1A/1B fit) with the standard size female threads of the turnbuckle bodies.

7.3.2 The thread in one head of each turnbuckle body shall be right-hand and in the other head, left-hand.

7.3.3 The threads on the end pulls shall be right-hand on one end pull and left-hand on the other. The length of the thread on the two end pulls shall be great enough so that the ends of the end pull can be brought into contact with each other at the middle of the body length when jam nuts are not used.

8. Dimensions and Tolerances

8.1 Turnbuckles covered by this specification shall be furnished in the sizes shown in Table 1 and Table 2, as specified (see 4.1.3).
8.1.1 The size of turnbuckle bodies and turnbuckles shall be the nominal major diameter of the threads in the heads and the clear opening between heads (which is approximately equal to the take up); thus, for a ¾ by 6-in. (19 by 152-mm) turnbuckle body, the heads shall be threaded for a ¾-in. (19-mm) nominal major diameter end pull, and the clear opening between heads shall be 6 in. (152 mm). The difference between the actual clear opening in the turnbuckle body and the nominal value given in Table 1 or 2 for the size specified shall not exceed 5 % of the nominal value.

8.1.2 The lengths of the heads of the turnbuckle bodies shall not be less than 1 ½ times the nominal outside diameter of the end pull for sizes up to 1 ¼ in. (32 mm), and 1 ¼ times for sizes 1 ½ in. (32 mm) and above.

8.2 Type I, Grade 4 turnbuckle bodies shall comply with the dimensional requirements given in Table 4 for the size specified.

8.3 For Types II and III turnbuckle bodies, holes in body shall be ¼ in. (6 mm) in diameter for sizes up to and including ½ in. (16 mm); holes in body for sizes larger than ½ in. (16 mm) shall be ½ in. (13 mm) in diameter (see Fig. 13 and Fig. 14, respectively).

8.4 Minimum dimensions for forged-eye end pulls are as shown in Table 5.

8.5 For arc- or gas-welded and resistance-welded eye end pulls, the outside diameter of the eye shall not be less than 3 ½ times the nominal diameter of the end pull. Nominal dimensions “D” and “B” (see Fig. 3 and Fig. 4) shall be in accordance with Table 5.

8.6 Forged-jaw end pulls shall comply with the dimensional requirements of Table 6.

8.6.1 In Fig. 5, the area of the cross section X-X shall be not less than 0.75 of the area corresponding to the nominal diameter. The area of the cross section Y-Y shall be not less than 0.40 of the area corresponding to the nominal diameter.

8.7 Arc- or gas-welded jaw end pulls shall comply with the dimensional requirements of Table 7.

8.7.1 In Fig. 6, the area of the cross section X-X shall be not less than 0.75 of the area corresponding to the nominal diameter. The area of the cross section Y-Y shall be not less than 0.40 of the area corresponding to the nominal diameter.

### Table 4: Type I, Grade 4 Dimensions of Open Turnbuckle Bodies Fabricated by Arc or Gas Welding, in. (mm)

<table>
<thead>
<tr>
<th>Size, D, Nominal, in.</th>
<th>Length, A, min</th>
<th>Thickness, B, min</th>
<th>Width, C, min</th>
<th>Thickness, E, min</th>
<th>Width, F, min</th>
<th>Size of All Fillet Welds, min</th>
</tr>
</thead>
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<td>⅛ (12.7)</td>
<td>⅛ (14.3)</td>
<td>⅛ (3.1)</td>
<td>⅛ (7.9)</td>
<td>⅛ (3.17)</td>
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<tr>
<td>¼</td>
<td>¼ (15.8)</td>
<td>¼ (17.5)</td>
<td>¼ (20.6)</td>
<td>¼ (4.7)</td>
<td>¼ (11.1)</td>
<td>¼ (4.76)</td>
</tr>
<tr>
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<td>⅜ (22.5)</td>
<td>⅜ (25.4)</td>
<td>⅜ (28.6)</td>
<td>⅜ (6.35)</td>
<td>⅜ (15.8)</td>
<td>⅜ (6.38)</td>
</tr>
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<td>⅔</td>
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<td>⅔ (31.7)</td>
<td>⅔ (36.5)</td>
<td>⅔ (7.9)</td>
<td>⅔ (20.6)</td>
<td>⅔ (7.93)</td>
</tr>
<tr>
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<td>⅝ (38.1)</td>
<td>⅝ (44.4)</td>
<td>⅝ (9.5)</td>
<td>⅝ (11.1)</td>
<td>⅝ (9.52)</td>
</tr>
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<td>⅞ (44.4)</td>
<td>⅞ (50.8)</td>
<td>⅞ (11.1)</td>
<td>⅞ (25.4)</td>
<td>⅞ (11.11)</td>
</tr>
<tr>
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<td>Ⅲ (15.8)</td>
<td>Ⅲ (17.5)</td>
<td>Ⅲ (20.6)</td>
<td>Ⅲ (4.7)</td>
<td>Ⅲ (11.1)</td>
<td>Ⅲ (4.76)</td>
</tr>
<tr>
<td>Ⅲ/4</td>
<td>Ⅲ/4 (15)</td>
<td>Ⅲ/4 (17)</td>
<td>Ⅲ/4 (20.6)</td>
<td>Ⅲ/4 (4.7)</td>
<td>Ⅲ/4 (11)</td>
<td>Ⅲ/4 (4.76)</td>
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<tr>
<td>Ⅲ/8</td>
<td>Ⅲ/8 (17.5)</td>
<td>Ⅲ/8 (20.6)</td>
<td>Ⅲ/8 (28.6)</td>
<td>Ⅲ/8 (7.9)</td>
<td>Ⅲ/8 (20.6)</td>
<td>Ⅲ/8 (7.93)</td>
</tr>
<tr>
<td>Ⅲ/16</td>
<td>Ⅲ/16 (20.6)</td>
<td>Ⅲ/16 (28.6)</td>
<td>Ⅲ/16 (4.76)</td>
<td>Ⅲ/16 (7.93)</td>
<td>Ⅲ/16 (20.6)</td>
<td>Ⅲ/16 (7.93)</td>
</tr>
</tbody>
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### Table 5: Dimensions of Eye End Pulls, in. (mm)

<table>
<thead>
<tr>
<th>D, Nominal, in.</th>
<th>A, min</th>
<th>B, min</th>
<th>C, min</th>
<th>E, min</th>
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</thead>
<tbody>
<tr>
<td>¼</td>
<td>(12.7)</td>
<td>(5.56)</td>
<td>¼</td>
<td>(8.73)</td>
</tr>
<tr>
<td>½</td>
<td>(7.36)</td>
<td>(4.76)</td>
<td>½</td>
<td>(11.9)</td>
</tr>
<tr>
<td>⅞</td>
<td>(4.94)</td>
<td>(2.54)</td>
<td>⅞</td>
<td>(4.12)</td>
</tr>
<tr>
<td>2</td>
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<td>(3.65)</td>
<td>2</td>
<td>(7.46)</td>
</tr>
<tr>
<td>⅞</td>
<td>(3.8)</td>
<td>(2.4)</td>
<td>⅞</td>
<td>(1.317)</td>
</tr>
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</table>

### Table 6: Dimensions of Forged-Jaw End Pulls, in. (mm)

<table>
<thead>
<tr>
<th>D, Nominal, in.</th>
<th>A, min</th>
<th>F, min</th>
<th>P, min</th>
<th>W, min</th>
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<tr>
<td>¼</td>
<td>(15.8)</td>
<td>(3.17)</td>
<td>¼</td>
<td>(6.35)</td>
</tr>
<tr>
<td>⅛</td>
<td>(17.5)</td>
<td>(4.76)</td>
<td>⅛</td>
<td>(9.52)</td>
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</tr>
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<td>(28.6)</td>
<td>(7.93)</td>
<td>⅛</td>
<td>(12.7)</td>
</tr>
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<td>⅛</td>
<td>(34.9)</td>
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<td>⅛</td>
<td>(25.4)</td>
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<td>(25.4)</td>
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<td>(46.2)</td>
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<td>(44.4)</td>
<td>(38.1)</td>
<td>⅛</td>
<td>(57.1)</td>
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<tr>
<td>⅛</td>
<td>(50.8)</td>
<td>(57.1)</td>
<td>⅛</td>
<td>(73.1)</td>
</tr>
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</table>

### Table 7: Dimensions of Open Turnbuckle Bodies Fabricated by Arc or Gas Welding, in. (mm)

<table>
<thead>
<tr>
<th>Size, D, Nominal, in.</th>
<th>Head</th>
<th>Rein</th>
<th>Size of All Fillet Welds, in.</th>
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<tbody>
<tr>
<td>⅛</td>
<td>⅛ (11.11)</td>
<td>⅛ (12.7)</td>
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<td>¼</td>
<td>¼ (15.8)</td>
<td>¼ (17.5)</td>
<td>¼ (4.76)</td>
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<td>⅜ (6.38)</td>
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</tr>
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<td>⅝ (38.1)</td>
<td>⅝ (9.52)</td>
</tr>
<tr>
<td>⅞</td>
<td>⅞ (39.7)</td>
<td>⅞ (44.4)</td>
<td>⅞ (11.1)</td>
</tr>
<tr>
<td>Ⅲ</td>
<td>Ⅲ (20.6)</td>
<td>Ⅲ (25.4)</td>
<td>Ⅲ (11.1)</td>
</tr>
<tr>
<td>Ⅲ/4</td>
<td>Ⅲ/4 (15)</td>
<td>Ⅲ/4 (17)</td>
<td>Ⅲ/4 (4.76)</td>
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<td>Ⅲ/8</td>
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<td>Ⅲ/64 (41.4)</td>
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</table>
8.8 Upset jaw ends shall comply with the dimensional requirements of Table 8.

8.8.1 In Fig. 7, the area of the cross section X-X shall be not less than 0.75 of the area corresponding to the nominal diameter. The area of the cross section Y-Y shall be not less than 0.40 of the area corresponding to the nominal diameter.

8.9 Hook end pulls shall comply with the dimensional requirements of Table 9.

8.10 Heavy jam nuts (see 5.1.3) shall conform to the dimensional requirements in accordance with ANSI B 18.2.2.

9. Workmanship, Finish, and Appearance

9.1 Turnbuckles and end pulls shall be finished in a workmanlike manner. All parts shall be properly shaped and shall be free from fins, cracks, flaws, seams, and other injurious defects.

9.1.1 Screw threads shall be true to form, clean cut, and free from injurious defects.

9.2 Turnbuckles and end pulls shall be finished by grinding the flash and excess weld metal smooth, where required, and the loose scale removed.

9.3 Turnbuckles shall be furnished self-colored, black, or zinc-coated, as specified (see 4.1.6).

9.3.1 If zinc-coated turnbuckles are specified, the coating may be applied by the hot-dip (galvanizing) process or the electrodeposition process at the manufacturer’s option.

### Table 7 Dimensions of Arc or Gas Welded-Jaw End Pulls, in. (mm)

<table>
<thead>
<tr>
<th>D, Nominal Size, in.</th>
<th>A, min</th>
<th>F, min</th>
<th>P, min</th>
<th>S, min</th>
<th>W, min</th>
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<td>1/4</td>
<td>(6.35)</td>
<td>1/4</td>
<td>(6.35)</td>
</tr>
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<td>5/32</td>
<td>(18.2)</td>
<td>(7.93)</td>
<td>3/32</td>
<td>(9.52)</td>
<td></td>
</tr>
<tr>
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<td>(25.1)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>3/8</td>
<td>(31.7)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
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<td>(38.1)</td>
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<td>1/4</td>
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<td>1/4</td>
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</tr>
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<td>(101.6)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>2 3/4</td>
<td>(107.9)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
</tbody>
</table>

### Table 8 Dimensions of Upset End Pulls, in. (mm)

<table>
<thead>
<tr>
<th>D, Nominal Size, in.</th>
<th>A, min</th>
<th>F, min</th>
<th>P, min</th>
<th>S, min</th>
<th>W, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>5/32</td>
<td>1/4</td>
<td>(6.35)</td>
<td>1/4</td>
<td>(6.35)</td>
</tr>
<tr>
<td>5/32</td>
<td>(18.2)</td>
<td>(7.93)</td>
<td>3/32</td>
<td>(9.52)</td>
<td></td>
</tr>
<tr>
<td>1/2</td>
<td>(25.1)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>3/8</td>
<td>(31.7)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>7/8</td>
<td>(38.1)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>1</td>
<td>(44.4)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>1 1/2</td>
<td>(50.8)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>1 3/8</td>
<td>(60.3)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>1 1/2</td>
<td>(69.8)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>1 3/8</td>
<td>(76.2)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>2</td>
<td>(95.2)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>2 1/2</td>
<td>(101.6)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>2 3/4</td>
<td>(107.9)</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
</tbody>
</table>

### Table 9 Dimensions of Hook End Pulls, in. (mm)

<table>
<thead>
<tr>
<th>D, Nominal Size, in.</th>
<th>A, min</th>
<th>B, min</th>
<th>C, min</th>
<th>L, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>7/32</td>
<td>1/4</td>
<td>(4.76)</td>
<td>1 1/32</td>
</tr>
<tr>
<td>5/32</td>
<td>(12.7)</td>
<td>1/4</td>
<td>(3.17)</td>
<td>1/16</td>
</tr>
<tr>
<td>1/2</td>
<td>(14.3)</td>
<td>1/4</td>
<td>(3.17)</td>
<td>11/16</td>
</tr>
<tr>
<td>3/8</td>
<td>(20.6)</td>
<td>1/4</td>
<td>(3.17)</td>
<td>11/16</td>
</tr>
<tr>
<td>1</td>
<td>(26.1)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
<tr>
<td>1 1/2</td>
<td>(31.7)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
<tr>
<td>1 3/8</td>
<td>(38.1)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
<tr>
<td>2</td>
<td>(44.4)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
<tr>
<td>2 1/2</td>
<td>(50.8)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
<tr>
<td>2 3/4</td>
<td>(57.1)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
<tr>
<td>3</td>
<td>(63.5)</td>
<td>1/4</td>
<td>(4.47)</td>
<td>1 7/32</td>
</tr>
</tbody>
</table>

9.3.1.1 If the hot-dip process is used, the coating shall be applied in accordance with Specification A 153 and shall be adherent, smooth, and free from injurious lumps, blisters, dross, or flux.

9.3.1.2 If the electrodeposition process is used, it shall conform to Type II finish, Class Fe/Zn 12 in accordance with Specification B 633.

9.3.2 Coating shall be done on the end pulls after threading; coating for turnbuckle bodies shall be done after tapping.
10. Sampling

10.1 All turnbuckles of the same type, grade, class, and size, not exceeding 1000 and presented at one time, shall be considered a lot.

10.2 A random sample of turnbuckles shall be selected from each lot in accordance with Table 10 for the examination specified in 12.2.

10.3 A random sample of turnbuckles shall be selected from each lot in accordance with Table 11 for the breaking strength, proof, bending, and galvanizing tests specified in Section 11.

10.3.1 End pull samples for bending tests shall be selected prior to threading.

10.3.2 Failure of any sample in any test shall be cause for rejection of the lot represented by the sample.

10.3.3 Specimens used for the breaking strength and bend tests may also be used for the galvanizing tests.

11. Test Methods

11.1 Proof Test—Each sample selected in accordance with 10.3 shall be subjected to a proof test of one half the specified breaking strength (see Table 1) for the end pull. Test loads shall be applied at end pulls.

11.2 Breaking Strength Test—Each sample turnbuckle selected in accordance with 10.3 shall be tested to failure. Loads shall be applied at end pulls.

11.3 Bending Test—Each end pull sample selected in accordance with 10.3 shall be bent cold through an angle of 90° around a pin twice the nominal diameter of the end pull.

11.4 Galvanizing Test—If the hot-dip zinc-coating method is used, no thickness test will be required. If the electrodeposition method is used, the thickness shall be determined as specified in Specification B 633.

11.5 Possible test failures are defined as follows:

11.5.1 Proof Test—Evidence of deformation or signs of incipient cracks in turnbuckle body or end pull as a result of specified proof test.

11.5.2 Breaking Strength Test—Breaking strength or turnbuckles equipped with end pulls less than the required minimum value.

11.5.3 Bending Test—Evidence of cracks or rupture when the unthreaded end pull is bent cold as required.

11.5.4 Galvanizing Test—Coating nonconformant; nonadherent, evidence of coat flaking off, or separating from basic metal; thickness less than the allowable minimum.

12. Inspection

12.1 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.

12.2 Each sample turnbuckle selected in accordance with Table 10 shall be examined to verify compliance with the requirements of this specification. Examination shall be conducted as specified in Table 12.

12.2.1 Any turnbuckle in the sample containing one or more defects shall be rejected. If any defects are noted in the original sample units, an additional sample quantity, in accordance with Table 10, shall be randomly selected; and if any defects are noted as specified in Table 12, this shall be cause for rejection of the lot represented by that sample.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Packaging and Package Marking

14.1 Unless otherwise specified (see 4.1.8), packaging shall conform to the manufacturer’s normal commercial practice, and in such a manner that will ensure acceptance by common carrier and afford protection against physical and mechanical damage during shipment. Shipping containers shall conform to carrier regulations as applicable to the mode of transportation.

### TABLE 10 Sampling for Examination

<table>
<thead>
<tr>
<th>Number of Turnbuckles in Lot</th>
<th>Number of Turnbuckles in Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 or under</td>
<td>10</td>
</tr>
<tr>
<td>41 to 110</td>
<td>15</td>
</tr>
<tr>
<td>111 to 300</td>
<td>25</td>
</tr>
<tr>
<td>301 to 500</td>
<td>35</td>
</tr>
<tr>
<td>501 to 800</td>
<td>50</td>
</tr>
<tr>
<td>801 to 1000</td>
<td>72</td>
</tr>
</tbody>
</table>

### TABLE 11 Sampling for Tests

<table>
<thead>
<tr>
<th>Number of Turnbuckles in Lot</th>
<th>Number of Samples to be Selected for:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proof</td>
</tr>
<tr>
<td>40 and under</td>
<td>3</td>
</tr>
<tr>
<td>41 to 110</td>
<td>5</td>
</tr>
<tr>
<td>111 to 300</td>
<td>7</td>
</tr>
<tr>
<td>301 to 500</td>
<td>10</td>
</tr>
<tr>
<td>501 to 1000</td>
<td>15</td>
</tr>
</tbody>
</table>
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only for direct government acquisition, when specified in the contract or order (see 4.1.8).

S1. General

S1.1 Navy Fire-Retardant Requirements:

S1.1.1 Treated Lumber and Plywood—When specified, all lumber and plywood including laminated veneer material used in shipping container and pallet construction, members, blocking, bracing, and reinforcing shall be fire-retardant treated material conforming to MIL-L-19140 as follows:

<table>
<thead>
<tr>
<th>Levels</th>
<th>Weather Resistant: Category I—General Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>A and B</td>
<td>Type II</td>
</tr>
<tr>
<td>C</td>
<td>Type I</td>
</tr>
<tr>
<td></td>
<td>Non-Weather Resistant: Category I—General Use</td>
</tr>
</tbody>
</table>

S1.1.2 Fiberboard—Fiberboard used in the construction of interior (unit and intermediate) and exterior fiberboard boxes, including interior packaging forms shall conform to the class domestic/fire retaradant or class weather resistant/fire retardant materials requirements as specified in PPP-F-320 and amendments thereto.

S1.1.3 Cushioning and Wrapping Materials—The use of excelsior, newspaper, shredded paper (all types), and similar hydroscopic or non-neutral materials and all types of loose fill materials for packaging applications such as cushioning, fill, stuffing, and dunnage is prohibited. Material selected for cushioning and wrapping shall have properties (characteristics) for resistance to fire. Cushioning or wrapping materials, as applicable, shall be provided to prevent item and package damage and to prevent free movement of the container contents.

S2. Preservation

S2.1 Preservation shall be Level A or commercial as specified.

S2.1.1 Level A—Turnbuckles except black coated and zinc coated, shall be preserved in accordance with Method I of MIL-P-116, using type P-1 or P-19 preservative. Black coated or zinc coated turnbuckles shall be preserved in accordance with Method III of MIL-P-116.

S2.1.1.1 Turnbuckles with a mass less than 5 lb (2.5 kg) each shall be packed in fiberboard boxes conforming to PPP-B-636, class weather resistant. Box closure shall conform to Method V as specified in the applicable box specification appendix. The gross mass of the boxes shall not exceed the limitations of the applicable box specification.

S2.1.1.2 Turnbuckles with a mass over 5 lb (2.5 kg) each shall be bulk packed in containers specified in Section S3.

S2.2 Commercial—Turnbuckles shall be preserved in accordance with Practice D 3951.

S3. Packing

S3.1 Packing shall be level A, B, or commercial as specified.

S3.1.1 General Requirements for Levels A, B, and C—Containers selected (see S3.1.2) shall be of minimum mass and cube consistent with the protection required, of uniform size, and contain identical quantities.

S3.1.2 Levels A, B, and C—Turnbuckles preserved as specified, shall be packed in exterior shipping containers in accordance with MIL-STD-2073-1, Table VII of Appendix C, for the level of packing specified. Unless otherwise specified container selection including container options shall be the contractor’s option.

S3.1.2.1 Closure, Gross Mass, and Waterproofing:

1. Closure—Container closure, reinforcing, or banding shall be in accordance with container specification or appendix thereto except that weather resistant fiberboard boxes shall be closed in accordance with Method V and reinforced with non-metallic or tape banding and domestic nonweather-resistant fiberboard boxes shall be closed in accordance with Method I using pressure-sensitive tape.

2. Mass—Wood, plywood, and wood cleated type containers whose mass exceeds 200 lb (90 kg) shall be modified by the addition of skids in accordance with MIL-STD-2073-1, Appendix F or the applicable container specification or appendix thereto.

3. Waterproofing—Unless otherwise specified, Level A and when specified Level B shipping containers shall be provided with case liners, linings, wraps, or shrouds in accordance with MIL-STD-1186.

S3.1.3 Commercial—Turnbuckles preserved as specified shall be packed for shipment in accordance with Practice D 3951 and herein.

S3.1.3.1 Container Modification—Shipping containers with mass exceeding 200 lb (90 kg) shall be provided with a minimum of two 3 by 4 in. (75 by100 mm) nominal wood skids laid flat, or a skid or sill-type base which will support the material and facilitate handling by mechanical handling equipment during shipment, stowage and storage.

S4. Palletized Unit Loads

S4.1 When specified, containers shall be palletized in accordance with MIL-STD 2073-1, Appendix F.
S5. Marking

S5.1 Levels A, B, C, and Commercial—In addition to any special marking required, interior (unit) packs, shipping containers, and palletized unit loads shall be marked in accordance with MIL-STD 2073-1, Appendix F for military agencies and FED-STD 123 for civil agencies and shall include bar codes and applicable packaging acquisition options herein as specified.
Standard Practice for Selection and Application of Piping System Materials\textsuperscript{1}

This standard is issued under the fixed designation F 1155; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\varepsilon\)) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is intended as a guide to shipbuilders, shipowners, and design agents for use in the preparation of piping system material schedules for commercial ship design and construction.

1.2 The materials and limitations listed in Tables 1-28 meet the minimum requirements of the U.S. Coast Guard and the American Bureau of Shipping and should be considered to be the minimum acceptable materials in regard to material, design, and testing. This document is not intended to limit the selection of material strictly to those listed. Other equal or superior materials may be used provided that they are acceptable to the regulatory bodies and classification societies.

2. Referenced Documents

2.1 ASTM Standards:

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless\textsuperscript{2}
A 105/A105M Specification for Carbon Steel Forgings for Piping Applications\textsuperscript{2}
A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service\textsuperscript{2}
A 134 Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)\textsuperscript{2}
A 139/A 139M Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)\textsuperscript{2}
A 178/A 178M Specification for Electric-ResistanceWelded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes\textsuperscript{2}
A 179/A 179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes\textsuperscript{2}
A 181/A 181M Specification for Carbon Steel Forgings, for General-Purpose Piping\textsuperscript{2}
A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service\textsuperscript{2}
A 192/A 192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service\textsuperscript{2}
A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service\textsuperscript{2}
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service\textsuperscript{2}
A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and HeatExchanger Tubes\textsuperscript{2}
A 214/A 214M Specification for Electric-ResistanceWelded Carbon Steel Heat-Exchanger and Condenser Tubes\textsuperscript{2}
A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service\textsuperscript{3}
A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service\textsuperscript{2}
A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel\textsuperscript{4}
A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes\textsuperscript{2}
A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates\textsuperscript{4}
A 307 Specification for Carbon Steel Bolts and Studs, 60 000 Psi Tensile Strength\textsuperscript{5}
A 320/A 320M Specification for Alloy Steel Bolting Materials for Low-Temperature Service\textsuperscript{2}
A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service\textsuperscript{2}
A 351/A 351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts\textsuperscript{3}
A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum\textsuperscript{4}
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures\textsuperscript{3}
A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service\textsuperscript{4}
A 536 Specification for Ductile Iron Castings\textsuperscript{3}
A 563 Specification for Carbon and Alloy Steel Nuts\textsuperscript{5}

B 61 Specification for Steam or Valve Bronze Castings
B 62 Specification for Composition Bronze or Ounce Metal Castings
B 88 Specification for Seamless Copper Water Tube
B 466 Specification for Seamless Copper-Nickel Pipe and Tube
B 467 Specification for Welded Copper-Nickel Pipe
D 2996 Specification for Filament-Wound “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D 2997 Specification for Centrifugally Cast “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D 4024 Specification for Machine Made “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Flanges
F 682 Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings
F 683 Practice for Selection and Application of Thermal Insulation for Piping and Machinery
F 704 Practice for Selecting Bolting Lengths for Piping System Flanged Joints
F 722 Specification for Welded Joints for Shipboard Piping Systems
F 1476 Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications
F 1548 Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings Used in Piping Applications

2.2 ANSI Standards:
B 16.5 Steel Pipe Flanges and Flanged Fittings
B 16.9 Factor Made Wrought Steel Buttwelding Fittings
B 16.10 Face to Face and End to End Dimensions of Valves
B 16.11 Forged Steel Fittings, Socket Welding and Threaded
B 16.15 Cast Bronze Threaded Fittings Class 125 and 250
B 16.18 Cast Copper Alloy Solder Joint Pressure Fittings
B 16.22 Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
B 16.24 Bronze Flanges and Flanged
B 16.28 Wrought Steel Buttwelding Short Radius Elbows and Returns
B 16.34 Valves Flanged, Threaded and Welding End
B 16.42 Ductile Iron Pipe Flanges and Flanged Fittings
B 18.2.1 Square and Hex Bolts and Screws Inch Series
B 18.2.2 Square and Hex Nuts (Inch Series)
B 31.1 Power Piping
B 36.10 Welded and Seamless Wrought Steel Pipe
B 36.19 Stainless Steel Pipe

2.3 Manufacturer’s Standardization Society of the Valve and Fitting Industry Standards:
SP-67 Butterfly Valves
SP-72 Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-80 Bronze Gate, Globe, Angle and Check Valves

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3. General Requirements

3.1 Shipboard piping systems shall be in accordance with ANSI B31.1 except as modified by 46 CFR Part 56 of the U.S. Coast Guard regulations and Sections 36 and 44 of the ABS’ Rules.

3.2 Piping systems shall be classed in accordance with 46 CFR 56.04.

3.3 Valves shall be in accordance with 46 CFR 56.20.

3.4 Valves for Class I systems shall be in accordance with 46 CFR 56.20-9(b) and if larger than 2-in. NPS shall not have socket weld ends.

3.5 Resilient seated valves shall be in accordance with 46 CFR 56.20-15.

3.6 Dimensions of ductile iron gate, globe, angle, and check valves shall be in accordance with ANSI B16.34 and shall use the adjusted pressure temperature ratings of ANSI B31.1, Appendix E.

3.7 Flanges for flanged valves and fittings and their companion flanges shall be in accordance with 46 CFR 56.25 and 56.30-10.

3.8 Bolting shall be in accordance with 46 CFR 56.25-20. Practice F 704 shall be used as a guide for determining flange bolting lengths.

3.9 Socket weld joints shall be in accordance with 46 CFR 56.30-5(c) and 56.30-10(b), Method 4, and shall not exceed 3-in. NPS for Class I and II-L service.

3.10 Threaded joints shall be in accordance with 46 CFR 56.30-20 and shall not exceed 2-in. NPS for Class I systems.

3.11 Flared, flareless, and compression tube fittings shall be limited to 2-in. OD or below and shall be in accordance with 46 CFR 56.30-25.3.12

3.12 Brazed socket type joints shall be in accordance with 46 CFR 56.30-30 and 56.75.

3.13 Gasketed mechanical couplings and fittings for use with gasketed mechanical couplings shall be in accordance with 46 CFR 56.30-35.

3.14 Flexible pipe couplings of the compression or slip-on types shall be in accordance with 46 CFR 56.30-40.

3.15 For restrictions on the use of welded tube and pipe, see 46 CFR 56.60-2(b).

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9 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
10 Available from Manufacturer’s Standardization Society of the Valve and Fittings Industry, 127 Park St., N.E. Vienna, VA 22180.
11 Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.
12 Available from American Bureau of Shipping, Book Order, 45 Eisenhower Dr., Paramus, NJ 07652.
3.16 Ferrous pipe used for saltwater service shall be protected against corrosion in accordance with 46 CFR 56.60-3(a).
3.17 All welding of Class I and II piping shall be in accordance with 46 CFR 56.70 and Specification F 722.
3.18 Thermal insulation for piping systems shall be in accordance with Practice F 683.
3.19 Fiberglass reinforced thermosetting epoxy resin pipe and fittings shall be in accordance with 46 CFR 56.60-25 and U.S. Coast Guard Navigation and Vessel Inspection Circular (NVIC) 11-86.
3.20 Fiberglass pipe shall not be used outboard of skin valves.

4. List of Tables
4.1 The tables are arranged in the following sequence:

<table>
<thead>
<tr>
<th>Title</th>
<th>Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Temperature Limitations</td>
<td>1</td>
</tr>
<tr>
<td>Steam, Steam Drains, Boiler Blow, and Superheater Safety Valve Escape Piping; 1100°F max</td>
<td>2</td>
</tr>
<tr>
<td>Steam, Steam Drains, Feed, Condensate, Boiler Blow, Sampling and Compounding, and Safety Valve Escape Piping; 775°F max</td>
<td>3</td>
</tr>
<tr>
<td>Steam, Steam Drains, Feed, Condensate, Boiler Blow, Sampling and Compounding, and Safety Valve Escape Piping; 406°F max</td>
<td>4</td>
</tr>
<tr>
<td>Gas Turbine and Diesel Exhaust Piping; 1100°F max</td>
<td>5</td>
</tr>
<tr>
<td>Gas Turbine and Diesel Exhaust Piping; 775°F max</td>
<td>6</td>
</tr>
<tr>
<td>Fresh Water for Auxiliary Machinery and Engine Cooling; 240°F max</td>
<td>7</td>
</tr>
<tr>
<td>Fresh Water, Hot and Cold Domestic, Air Conditioning and Sanitary</td>
<td>8</td>
</tr>
<tr>
<td>Seawater Circulating, Wet Firemain, and Distilling Plant Piping</td>
<td>9</td>
</tr>
<tr>
<td>Dry Firemain, Foam, Sprinkling, Deckwash, and Tank Cleaning Piping</td>
<td>10</td>
</tr>
<tr>
<td>Bilge, Clean Ballast, and Pump Priming Piping</td>
<td>11</td>
</tr>
<tr>
<td>Diesel and Lube Oil System Piping, Fuel Oil Filting Transfer, and Service Suction Piping</td>
<td>12</td>
</tr>
<tr>
<td>Fuel Oil Service Discharge Piping</td>
<td>13</td>
</tr>
<tr>
<td>Cargo Oil (and Vent Piping) and Crude Oil Wash Piping</td>
<td>14</td>
</tr>
<tr>
<td>Steering Gear Fill and Drain Piping, and Telemotor Piping</td>
<td>15</td>
</tr>
<tr>
<td>Hydraulic Piping</td>
<td>16</td>
</tr>
<tr>
<td>Air Piping 150 psi and Below</td>
<td>17</td>
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<tr>
<td>Air Piping Above 150 psi</td>
<td>18</td>
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<tr>
<td>Refrigeration Piping</td>
<td>19</td>
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<tr>
<td>CO₂, Halon, and Smoke Detection</td>
<td>20</td>
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<tr>
<td>Sounding Tubes, Vents, and Overflows for Fresh Water, Saltwater and Oil</td>
<td>21</td>
</tr>
<tr>
<td>Waste, Soil, and Interior Deck Drains</td>
<td>22</td>
</tr>
<tr>
<td>Weather Deck Drains, Main Deck, and Above</td>
<td>23</td>
</tr>
<tr>
<td>Inert Gas—Generator or Uptakes to Scrubber</td>
<td>24</td>
</tr>
<tr>
<td>Inert Gas—Scrubber to Tanks</td>
<td>25</td>
</tr>
<tr>
<td>Liquified Natural Gas Systems Including Vapor Fuel, Inert Gas, Nitrogen Service</td>
<td>26</td>
</tr>
<tr>
<td>Liquified Natural Gas Systems Including Cargo, Inert Gas, Nitrogen, and Cargo Tank Cooldown and Warmup Piping Below 0°F</td>
<td>27</td>
</tr>
<tr>
<td>Valve Trim Groups</td>
<td>28</td>
</tr>
</tbody>
</table>

5. Keywords
5.1 materials; piping systems; piping systems materials; ship construction; ship design
<table>
<thead>
<tr>
<th>Material</th>
<th>Material Specifications</th>
<th>Temperature Limit, °F, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion resistant steel</td>
<td>ASTM A 194/A 194M GR B 8, 8C, 8T</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>ASTM A 194/A 194M GR 8F</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>ASME SA312 TP C 316L</td>
<td>850</td>
</tr>
<tr>
<td>Chrome-molybdenum steel</td>
<td>ASTM A 193/A 193M GR B16</td>
<td>1100</td>
</tr>
<tr>
<td></td>
<td>ASTM A 193/A 193M GF B7</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>ASTM A 234/A 234M GR WP11</td>
<td>1100</td>
</tr>
<tr>
<td>Carbon steel</td>
<td>ASTM A 53 TY D</td>
<td>800F</td>
</tr>
<tr>
<td></td>
<td>ASTM A 53 TY E</td>
<td>650</td>
</tr>
<tr>
<td>Ductile iron</td>
<td>ASTM A 105/A 105M</td>
<td>800E</td>
</tr>
<tr>
<td></td>
<td>ASTM A 106</td>
<td>800E</td>
</tr>
<tr>
<td></td>
<td>ASTM A 134 GR 285C (straight seam)</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>ASTM A 134 GR 285C (spiral seam)</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>ASTM A 139/A 139M GR B (straight seam)</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>ASTM A 139/A 139M GR B (spiral seam)</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>ASTM A 181/A 181M</td>
<td>800E</td>
</tr>
<tr>
<td></td>
<td>ASTM A 194/A 194M GR 2H</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>ASTM A 216/A 216M GR WCB</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>ASTM A 307</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>ASTM A 515/A 515M GR 70</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>ASTM A 395</td>
<td>650</td>
</tr>
<tr>
<td>Bronze</td>
<td>ASME SB61</td>
<td>550</td>
</tr>
<tr>
<td>Copper nickel alloy</td>
<td>ASME SB46 C70600</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>ASME SB46 C70600</td>
<td>600</td>
</tr>
<tr>
<td>Glass reinforced plastic</td>
<td>ASTM D 2996 GR 1</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>ASTM D 2997 GR 1</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>ASTM D 4024 GR 1</td>
<td>225</td>
</tr>
</tbody>
</table>

---

A Maximum temperature limits per ANSI B31.1 for all material, except glass reinforced plastic, which is per NVIC 11-86 and Specification A 536 which is per 46 CFR 56.

B GR—grade.

C TP—tubular product.

D TY—type.

E Upon prolonged exposure to temperatures above 775°F, the carbide phase or carbon steel may be converted to graphite.
### TABLE 2  Steam, Steam Drains, Boiler Blow, Superheater Safety Valve Escape Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe</strong></td>
<td>Seamless</td>
<td>CrMo C steel</td>
<td>ASTM A 335/A 335M GR C P11</td>
<td>ANSI B36.10</td>
<td>1100°F</td>
</tr>
<tr>
<td><strong>Takedown joints</strong></td>
<td>Flanges: weld neck or socket weld</td>
<td>CrMo steel</td>
<td>ASTM A 182/A 182M GR F11</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td><strong>Bolting</strong></td>
<td>Bolts/bolt studs</td>
<td>CrMoV steel</td>
<td>ASTM A 193/A 193M GR B16</td>
<td>ANSI B18.2.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>CMo steel</td>
<td>ASTM A 194/A 194M GR 4</td>
<td>ANSI B18.2.2</td>
<td></td>
</tr>
<tr>
<td><strong>Fittings</strong></td>
<td>Flanged</td>
<td>CrMo steel</td>
<td>ASME SA217 GR WC6 or</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Buttweld</td>
<td>CrMo steel</td>
<td>ASTM A 182/A 182M GR F11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>CrMo steel</td>
<td>ASTM A 182/A 182M GR F11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Valves: gate, globe, angle, check</strong></td>
<td>Flanged or butt weld</td>
<td>CrMo steel</td>
<td>ASME SA217 GR WC6 or</td>
<td>ANSI B16.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>CrMo steel</td>
<td>ASTM A 182/A 182M GR F11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks/Limitations**

- **A** Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
- **B** CrMo—chromium-molybdenum.
- **C** Gr—grade.
- **D** CrMoV—chromium-molybdenum-vanadium.
- **E** CMo—carbon-molybdenum.
- **F** For trim group definition, refer to Table 28.

### TABLE 3  Steam, Steam Drains, Feed, Condensate Boiler Blow Sampling and Compounding, Safety Valve Escape Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe</strong></td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR B or A 53 GR B TY S or E</td>
<td>ANSI B36.10</td>
<td>775°F</td>
</tr>
<tr>
<td><strong>Takedown joints</strong></td>
<td>Flanges: weld neck, socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td></td>
</tr>
<tr>
<td><strong>Bolting</strong></td>
<td>Bolts/bolt studs</td>
<td>CrMo steel</td>
<td>ASTM A 193/A 193M GR B7</td>
<td>ANSI B18.2.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 194/A 194M GR 2H</td>
<td>ANSI B18.2.2</td>
<td></td>
</tr>
<tr>
<td><strong>Fittings</strong></td>
<td>Flanged</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Buttweld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Valves: gate, globe, angle, check</strong></td>
<td>Flanged or butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WPB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td></td>
</tr>
</tbody>
</table>

**Remarks/Limitations**

- **A** Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
- **B** Gr—grade.
- **C** TY—type.
- **D** CrMo—chromium-molybdenum
- **E** For trim group definition, refer to Table 28.
- **F** Limited to a design pressure of 350 psig. See also Table 1.
### TABLE 4  Steam, Steam Drains, Feed, Condensate, Boiler Blow Sampling and Compounding, and Safety Valve Escape Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Style</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 406°F</th>
<th>Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR B or A 53 GR B TY S or E</td>
<td>ANSI B36.10</td>
<td>406°F</td>
<td>A 53 GR B TY S E limited to a design pressure of 350 psig</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weld neck, socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: threaded or brazed</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Fittings</td>
<td>Flanged</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or</td>
<td>ANSI B16.5</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Buttweld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or</td>
<td>ANSI B16.11</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Sleeve couplings</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Threaded or brazed</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASME A 395</td>
<td>ANSI B16.34</td>
<td>...</td>
<td>Trim group 3 and 4 F</td>
</tr>
<tr>
<td></td>
<td>Flanged or buttweld</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or</td>
<td>ANSI B16.34</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Threaded or brazed</td>
<td>Carbon steel</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-80</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

A When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
B Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
C GR—grade.
D TY—type.
E For trim group definition, refer to Table 28.
F MSS-SP-80 valves limited to 75% of valve design pressure.

### TABLE 5  Gas Turbine and Diesel Exhaust Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 1100°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless</td>
<td>CrMo steel</td>
<td>ASTM A 335/A 335M GR</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Plate formed</td>
<td>CrMo steel</td>
<td>ASTM A 387/A 387M</td>
<td>Commercial</td>
<td>...</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weld neck or socket weld</td>
<td>CrMo steel</td>
<td>ASTM A 182/A 182M GR F11</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Flanges: plate</td>
<td>CrMo steel</td>
<td>ASTM A 387/A 387M</td>
<td>Commercial</td>
<td>...</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>CrMoV steel</td>
<td>ASTM A 193/A 193M GR B16</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>CMo steel</td>
<td>ASTM A 194/A 194M GR 4</td>
<td>ANSI B18.2.2</td>
<td>...</td>
</tr>
</tbody>
</table>

A Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
B CrMo—chromium-molybdenum.
C GR—grade.
D Specific Coast Guard and ABS approval for design required.
E CrMoV—chromium-molybdenum-vanadium.
F CMo—carbon-molybdenum.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 775°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR® B or A 53</td>
<td>ANSI B36.10</td>
<td>775°F</td>
</tr>
<tr>
<td></td>
<td>welded</td>
<td></td>
<td>GR B TY S or E</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Takedown joints</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: weld neck, socket</td>
<td>Carbon steel</td>
<td>ASTM A 515/A 515M</td>
<td>Commercial°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>weld or slip-on</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>CrMo® steel</td>
<td>ASTM A 193/A 193M GR 87</td>
<td>ANSI B18.2.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 194/A 194M GR 2H</td>
<td>ANSI B18.2.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fittings</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanged</td>
<td></td>
<td>WCB or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
^GR—grade.
^Specific Coast Guard and ABS approval required.
^CrMo—chromium-molybdenum.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification(^a)</th>
<th>Design Specification</th>
<th>Maximum Temperature 240°F(^c) Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe</strong></td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR C or ASTM A 53 GR B TY S or E</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Filament wound</td>
<td>FGP(^e)</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial(^f)</td>
<td>See Table 1 and NVIC 11-86(^g)</td>
</tr>
<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP(^e)</td>
<td>ASTM D 2997 GR1</td>
<td>Commercial(^f)</td>
<td></td>
</tr>
<tr>
<td><strong>Takedown joints</strong></td>
<td>Flanges: socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: threaded or brazed</td>
<td>Bronze</td>
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<td>MIL-F-1183</td>
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<td>Flanges: adhesive bonded</td>
<td>GRP(^f)</td>
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<td>ASTM D 4024</td>
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<td>Ductile iron</td>
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<td>ASTM F 1476</td>
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<td>ANSI B16.9 or B16.28</td>
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<td>Trimm group 4(^4)</td>
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<td>Valves: gate, globe, angle, check</td>
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</tbody>
</table>

\(^a\)When combining dissimilar materials, galvanic corrosion can occur especially in seawater systems, and should be considered.\
\(^b\)Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.\n\(^c\)GR—grade.\n\(^d\)TY—type.\n\(^e\)FGP—fiberglass pipe.\n\(^f\)Specific Coast Guard and ABS approval required.\n\(^g\)For U.S. flag vessels in addition to classification society requirements.\n\(^h\)GRP—glass reinforced plastic.\n\(^i\)For trim group definition, refer to Table 28.\n\(^j\)MSS-SP-80 valves limited to 75 % of valve design pressure.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification(^a)</th>
<th>Design Specification</th>
<th>Maximum Temperature 240°F(^b)</th>
<th>Remarks/Limitations</th>
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</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless</td>
<td>Copper</td>
<td>ASTM B 88 TY(^c) K or L</td>
<td>ASTM B 88</td>
<td>Hard drawn. Must be annealed for pressures greater than 225 psig.</td>
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<tr>
<td></td>
<td>Filament wound</td>
<td>FGP(^d)</td>
<td>ASTM D 2996 GR(^e) 1</td>
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<td>See Table 1 and NVIC 11-86(^g)</td>
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<td>Centrifugally cast</td>
<td>FGP(^d)</td>
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<td>See Table 1 and NVIC 11-86(^g)</td>
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<tr>
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<td>Flanges: silbraze</td>
<td>Bronze</td>
<td>ASME SB62</td>
<td>ANSI B16.24</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Unions: brazed or threaded</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>GRP(^i)</td>
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<td>ASTM D 4024</td>
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<tr>
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<td>Gaskets: mechanical couplings</td>
<td>Ductile iron(^l)</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
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<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Feet/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
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<td>Nuts</td>
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<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
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<tr>
<td>Fittings</td>
<td>Silbraze</td>
<td>Copper</td>
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<td>ANSI B16.22</td>
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<td>Adhesive bonded</td>
<td>GRP(^j)</td>
<td>Commercial</td>
<td>Commercial(^l)</td>
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</tr>
<tr>
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<td>Used with gasketed mechanical couplings</td>
<td>Bronze</td>
<td>ASTM B 61 or B 62</td>
<td>ASTM F 1476</td>
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<tr>
<td>Valves</td>
<td>Butterfly wafer or lug</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
<td>Trim group 4(^j)</td>
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<td>Butterfly grooved end</td>
<td>Bronze</td>
<td>ASTM B 61 or B 62</td>
<td>...</td>
<td>Trim group 4(^j)</td>
<td></td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged or brazed</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-80(^k)</td>
<td>Trim group 4(^j)</td>
<td></td>
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<tr>
<td>Valves: ball</td>
<td>Flanged</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-72</td>
<td>Trim group 4(^j)</td>
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</table>

\(^a\)When combining dissimilar materials galvanic corrosion can occur, especially in seawater systems, and should be considered.
\(^b\)Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
\(^c\)TY—type.
\(^d\)FGP—fiberglass pipe.
\(^e\)GR—grade.
\(^f\)Specific Coast Guard and ABS approval required.
\(^g\)For U.S. flag vessels in addition to classification society requirements.
\(^h\)GRP—glass reinforced plastic.
\(^i\)Acceptable when gasket isolates coupling housings from fluid.
\(^j\)For trim group definition, refer to Table 28.
\(^k\)MSS-SP-80 valves limited to 75% of valve design pressure.
## TABLE 9  Sea Water Circulating, Wet Firemain, and Distilling Plant Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 150°F Remarks/Limitations</th>
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<td>CNA 90:10</td>
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<td>ASME SB466 or SB467</td>
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<td>ASTM D 2996 GR 1</td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
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<td>Bronze</td>
<td>ASME SB62</td>
<td>ANSI B16.24</td>
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</tr>
<tr>
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<td>Unions: brazed</td>
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<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
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<td></td>
<td>Brazed</td>
<td>GRP</td>
<td>ASTM D 4024 GR 1</td>
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<td>Gasketed</td>
<td>Ductile iron</td>
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<td>ASTM F 1476</td>
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<td>Mechanical</td>
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</tr>
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<td>Takedown joints</td>
<td>Flanges: brazed</td>
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<td>GRP</td>
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<td>ASTM B 61 or B 62</td>
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<td>ASME SB61 or SB62</td>
<td>MSS-SP-80</td>
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</tbody>
</table>

- **Pipe**: Seamless or welded, Centrifugally cast.
- **Flanges**: Brazed, Adhesive bonded.
- **Unions**: Brazed.
- **Bolting**: Bolts/bolt studs, Nuts.
- **Fittings**: Brazed, Adhesive bonded, Mechanical couplings.
- **Butt weld or welding sleeve**: CNA 90:10.
- **Valves**: Butterfly water or lug, Butterfly grooved, Flanged.

- **Remarks/Limitations**: See NVIC 11-86.

- **Material Specifications**: See Table 1.
- **Design Specifications**: See Table 1.
- **Pressure/temperature ratings**: Consult applicable material and design specifications.
- **Gaskets**: Used with mechanical couplings.
- **Acceptable when gasket isolates coupling housings from fluid.**
- **Trim group definition**: Refer to Table 28.

---

**Footnotes**:
- When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
- CNA—copper nickel alloy.
- FGP—fiberglass pipe.
- GRP—grade.
- Specific Coast Guard and ABS approval required.
- For U.S. flag vessels in addition to classification society requirements.
- GRP—glass reinforced plastic.
- Acceptable when gasket isolates coupling housings from fluid.
- Not permitted with CNA piping.
- Trim group definition, refer to Table 28.
- MSS-SP-80 valves limited to 75 % of valve design pressure.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification(^a)</th>
<th>Design Specification</th>
<th>Maximum Temperature 200°F B Remarks/Limitations</th>
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<td>Valves</td>
<td>Butterfly wafer or lug type</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
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<td>Ductile iron</td>
<td>ASTM A 536</td>
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<td>Trim group 4(^e)</td>
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<tr>
<td>Valves: gate, globe, angle, check</td>
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<td>ANSI B16.34</td>
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<td>Socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Flanged or threaded</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-80(^e)</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>...</td>
<td>Trim group 3 and 4(^e)</td>
</tr>
</tbody>
</table>

\(^{a}\)When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.

\(^{b}\)Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

\(^{c}\)GR—grade.

\(^{d}\)TY—type.

\(^{e}\)For trim group definition, refer to Table 28.

\(^{f}\)MSS-SP-80 valves limited to 75 % of valve design pressure.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification(^a)</th>
<th>Design Specification</th>
<th>Maximum Temperature 100°F</th>
<th>Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance weld</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR(^c) B or A 53</td>
<td>ANSI B36.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Filament wound</td>
<td>FGP(^e)</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial(^f)</td>
<td>See NVIC 11-86(^g)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP(^e)</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial(^f)</td>
<td>See NVIC 11-86(^g)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: slip-on or socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: plate</td>
<td>Steel with NCA(^h) facing</td>
<td>ASTM A 283/A 283M</td>
<td>ANSI B16.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>Gasketed mechanical couplings</td>
<td>GRP(^i)</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fittings</td>
<td>Ball stud</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleeve coupling</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesive bonded</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1548</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Used with gasketed</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Valves: butterfly water or lug type</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Butterfly grooved</td>
<td>Ductile iron</td>
<td>ASTM A 216/216M GR WCB or A 105/A 105M</td>
<td></td>
<td></td>
<td>Trim group 4(^j)</td>
</tr>
<tr>
<td></td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>ANSI B16.34</td>
<td>Trim group 3 and 4(^k)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Threaded or brazed</td>
<td>Bronze</td>
<td>ASTM A 216/216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>Trim group 3 and 4(^k)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grooved</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td></td>
<td>Trim group 3 and 4(^k)</td>
</tr>
</tbody>
</table>

\(^a\)When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
\(^b\)Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
\(^c\)Grade.
\(^d\)Type.
\(^e\)FGP—fiberglass pipe.
\(^f\)Specific Coast Guard and ABS approval required.
\(^g\)For U.S. flag vessels in addition to classification society requirements.
\(^h\)NCA—nickel copper alloy.
\(^i\)GRP—glass-reinforced plastic.
\(^j\)For trim group definition, refer to Table 28.
\(^k\)MSS-SP-80 valves limited to 75 % of valve design pressure.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 200°F&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR&lt;sup&gt;b&lt;/sup&gt; B or A 53 GR B TY&lt;sup&gt;c&lt;/sup&gt; S or E</td>
<td>ANSI B36.10</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filament wound</td>
<td>FGP&lt;sup&gt;d&lt;/sup&gt;</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial&lt;sup&gt;e&lt;/sup&gt;</td>
<td>See NVIC 11-86&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP&lt;sup&gt;d&lt;/sup&gt;</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial&lt;sup&gt;e&lt;/sup&gt;</td>
<td>See NVIC 11-86&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Takedown joints</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Flanges: weldneck, socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>GRP&lt;sup&gt;g&lt;/sup&gt;</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Bolts</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Fittings</td>
<td>Butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.11</td>
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</tr>
<tr>
<td></td>
<td>Sleeve couplings</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Adhesive bonded</td>
<td>GRP&lt;sup&gt;g&lt;/sup&gt;</td>
<td>Commercial</td>
<td>Commercial&lt;sup&gt;e&lt;/sup&gt;</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Used with gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1548</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly wafer or lug</td>
<td>Ductile iron</td>
<td>ASTM A 995</td>
<td>MSS-SP-67</td>
<td>Trim group 4 and 5&lt;sup&gt;h&lt;/sup&gt;</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Butterfly grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>...</td>
<td>Trim group 4&lt;sup&gt;h&lt;/sup&gt;</td>
<td>...</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 995</td>
<td>ANSI B16.34</td>
<td>Trim group 4 and 5&lt;sup&gt;h&lt;/sup&gt;</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>Trim group 3&lt;sup&gt;h&lt;/sup&gt;</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>...</td>
<td>Trim group 3 and 4&lt;sup&gt;h&lt;/sup&gt;</td>
<td>...</td>
</tr>
</tbody>
</table>

<sup>a</sup>Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
<sup>b</sup>GR—grade.
<sup>c</sup>TY—type.
<sup>d</sup>FGP—fiberglass pipe.
<sup>e</sup>Specific Coast Guard and ABS approval required.
<sup>f</sup>For U.S. flag vessel in addition to classification society requirements.
<sup>g</sup>GRP—glass reinforced plastic.
<sup>h</sup>For trim group definition, refer to Table 28.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 300°F Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR B or A 53 GR B TY S</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weldneck, socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
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</tr>
<tr>
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<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
<td>...</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
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</tr>
<tr>
<td>Fittings</td>
<td>Buttweld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.11</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Sleeve couplings</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.11</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Used with gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 682</td>
<td>...</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Trim group 4D</td>
</tr>
<tr>
<td>Valves; gate, globe, angle, check</td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>ANSI B16.34</td>
<td>Trim group 4 and 5D</td>
</tr>
<tr>
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<td>Butt weld or socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>Trim group 3D</td>
</tr>
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<td></td>
</tr>
<tr>
<td></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Trim group 3 and 4D</td>
</tr>
</tbody>
</table>

aConsult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
bGR grade.

cTY type.
dFor trim group definition, refer to Table 28.
### TABLE 14 Cargo Oil and Vent Piping and Crude Oil Wash Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 200°F Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR B or A 53 GR B TY S or E</td>
<td>ANSI B36.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filament wound</td>
<td>FGP</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial</td>
<td>See NVIC 11-86</td>
</tr>
<tr>
<td></td>
<td>Centrífugally cast</td>
<td>FGP</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial</td>
<td>See NVIC 11-86</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weld neck, socket weld, or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
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<td>Unions: socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexible couplings</td>
<td>Steel with resilient gasket</td>
<td>Commercial</td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>GFR</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
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</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
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<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
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<tr>
<td>Fittings</td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>ANSI B16.42</td>
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<tr>
<td></td>
<td>Butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB</td>
<td>ANSI B16.5</td>
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<tr>
<td></td>
<td>Socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
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</tr>
<tr>
<td></td>
<td>Sleeve coupling</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesive bonded</td>
<td>GFR</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Used with gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1548</td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly wafer or lug</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
<td>Trim group 4†</td>
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<tr>
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<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
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<td>Trim group 3†</td>
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</tr>
<tr>
<td></td>
<td>Butterfly grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>. . .</td>
<td>Trim group 4†</td>
</tr>
<tr>
<td></td>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>ASTM A 395</td>
<td>ANSI B16.34</td>
<td>Trim group 4†</td>
</tr>
<tr>
<td></td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>. . .</td>
<td>Trim group 3 and 4†</td>
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<tr>
<td></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>. . .</td>
<td>. . .</td>
</tr>
</tbody>
</table>

*Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

GR—grade.

type.

FGP—fiberglass pipe.

Specific Coast Guard and ABS approval required.

rFor U.S. flag vessel in addition to classification society requirements.

GRP—glass reinforced plastic.

*For trim group definition, refer to Table 28.

### TABLE 15 Steering Gear Fill and Drain Piping, and Telemotor Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature 406°F Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless</td>
<td>Copper</td>
<td>ASTM B 88 TY K</td>
<td>ASTM B 88</td>
<td>Must be annealed for pressures over 225 psig</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Unions: brazed or threaded</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>None required</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>ANSI B16.18</td>
<td></td>
</tr>
<tr>
<td>Fittings</td>
<td>Brazed</td>
<td>Copper</td>
<td>ASME SB75</td>
<td>ANSI B16.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brazed</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-80C</td>
<td>Trim groupD</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-72, Table 2</td>
<td>Trim groupD</td>
</tr>
</tbody>
</table>

*Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

TY—type.

MSS-SP-80 valves limited to 75% of valve design pressure.

*For trim group definition, refer to Table 28.
# TABLE 16 Hydraulic Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106, A 178/A 178M, A 179/A 179M, A 192/ A 192M or A 214/A 214M</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weldneck or socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>CrMo steel</td>
<td>ASTM A 193/A 193M GR&lt;sup&gt;©&lt;/sup&gt; B7</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td>Fittings</td>
<td>Butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.9 or B16.2B</td>
<td>...</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged or butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>Trim group 2&lt;sup&gt;©&lt;/sup&gt;</td>
</tr>
<tr>
<td>Valves: ball</td>
<td>Flanged</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-72</td>
<td>Trim group 3 and 4&lt;sup&gt;©&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>©</sup>This table does not apply to packaged hydraulic systems and equipment. For such applications, specific Coast Guard and ABS approval should be obtained.
<sup>©</sup>Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
<sup>©</sup>When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
<sup>©</sup>CRES—corrosion resistant steel.
<sup>©</sup>Specific Coast Guard and ABS approval required.
<sup>©</sup>CrMo—chromium-molybdenum.
<sup>©</sup>GR—grade.
<sup>©</sup>For trim group definition, refer to Table 28.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature Ambient&lt;sup&gt;a&lt;/sup&gt; Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe</strong></td>
<td>Seamless</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR&lt;sup&gt;c&lt;/sup&gt; B</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Seamless</td>
<td>Copper</td>
<td>ASTM B 88 TY&lt;sup&gt;d&lt;/sup&gt; K</td>
<td>ANSI B 88</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Filament wound</td>
<td>FGP&lt;sup&gt;e&lt;/sup&gt;</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial&lt;sup&gt;f&lt;/sup&gt;</td>
<td>See NVIC 11-86&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP&lt;sup&gt;e&lt;/sup&gt;</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial&lt;sup&gt;f&lt;/sup&gt;</td>
<td>See NVIC 11-86&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Takedown joints</strong></td>
<td>Flanges: socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: brazed</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>GRP&lt;sup&gt;f&lt;/sup&gt;</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
<td>...</td>
</tr>
<tr>
<td><strong>Bolting</strong></td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td>...</td>
</tr>
<tr>
<td><strong>Fittings</strong></td>
<td>Flanged</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Butt weld</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B15.9 or B16.28</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.11</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brazed</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MIL-F-1183</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Adhesive bonded</td>
<td>GRP&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Commercial&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Commercial&lt;sup&gt;f&lt;/sup&gt;</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Sleeve coupling</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Used with gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1548</td>
<td>...</td>
</tr>
<tr>
<td><strong>Valves</strong></td>
<td>Butterfly grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>...</td>
<td>Trim group 4&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>ASTM A 395</td>
<td>ANSI B16.34</td>
<td>Trim group 4&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Valves: gate, globe</td>
<td>Ductile iron</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>Trim group 3&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>angle, check</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>Trim group 3&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Brazed or threaded</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-80&lt;sup&gt;j&lt;/sup&gt;</td>
<td>Trim group 4&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>...</td>
<td>Trim group 3 and 4&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Valves: ball</td>
<td>Flanged</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-72</td>
<td>Trim group 4&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
<sup>b</sup>Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
<sup>c</sup>GR—grade.
<sup>d</sup>TY—type.
<sup>e</sup>FGP—fiberglass pipe.
<sup>f</sup>Specific Coast Guard and ABS approval required.
<sup>g</sup>For U.S. flag vessels in addition to classification society requirements.
<sup>h</sup>GRP—glass reinforced plastic.
<sup>i</sup>For trim group definition, refer to Table 28.
<sup>j</sup>MSS-SP-80 valves limited to 75% of valve design pressure.
### TABLE 18 Air Piping Above 150 psi

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature Ambient&lt;sup&gt;a&lt;/sup&gt; Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR® B or A 53 GR B TY S or E</td>
<td>ANSI B36.10</td>
<td>A 53 GR  B TY&lt;sup&gt;c&lt;/sup&gt; E limited to a design pressure of 350 psig</td>
</tr>
<tr>
<td></td>
<td>resistance welded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weld neck, socket</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>or slip-on</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>threaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gasketed</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>mechanical couplings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td></td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td>...</td>
</tr>
<tr>
<td>Fittings</td>
<td>Flanged</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WCB or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Butt weld</td>
<td></td>
<td>ASTM A 234/A 234M GR</td>
<td>ANSI B16.9 or B16.28</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WPB</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td></td>
<td>ASTM A 234/A 234M GR</td>
<td>ANSI B16.11</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WPB or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleeve coupling</td>
<td></td>
<td>ASTM A 234/A 234M GR</td>
<td>ASTM F 682</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WPB</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Used with</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1548</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>gasketed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mechanical couplings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly grooved</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td>Trim group 4&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR</td>
<td>ANSI B16.34</td>
<td>Trim group 3&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WCB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td></td>
<td>ASTM A 234/A 234M GR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WPB or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valves: ball</td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 216/A 216M GR</td>
<td>...</td>
<td>Trim group 3 and 4&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Flanged or butt weld</td>
<td>Carbon steel</td>
<td></td>
<td>MSS-SP-72</td>
<td>Trim group 3&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

<sup>b</sup> GR—grade.

<sup>c</sup> TY—type.

<sup>d</sup> For trim group definition, refer to Table 28.

### TABLE 19 Refrigeration Piping

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature Ambient&lt;sup&gt;a&lt;/sup&gt; Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless</td>
<td>Copper</td>
<td>ASTM B 88 TY® K or L or ASME SB75</td>
<td>ASTM B 88 or ASME SB75</td>
<td>Must be annealed for pressures over 225 psig</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>None</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Brazed</td>
<td>Copper</td>
<td>ASTM B 88 TY K or L or ASME SB75</td>
<td>ANSI B16.22</td>
<td>...</td>
</tr>
</tbody>
</table>

<sup>a</sup> Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

<sup>b</sup> TY—type.
### TABLE 20 CO₂, Halon, and Smoke Detection

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature $850^\circ F$ Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR^D B or A 53 GR B TY^E S</td>
<td>ANSI B36.10</td>
<td>See Table 1. Must be internally and externally protected from corrosion. CO₂ piping requires 6000-psig burst rating.</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: butt weld or socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>CrMo^C steel</td>
<td>ASTM A 193/A 193M GR B7</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 194/A 194M GR 2H</td>
<td>ANSI B18.2.2</td>
<td>...</td>
</tr>
<tr>
<td>Fittings</td>
<td>Buttweld, socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB A 105/A 105M</td>
<td>ANSI B16.9 or B16.28</td>
<td>...</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged or butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB or A 105/A 105M</td>
<td>ANSI B16.34 Trim group 2^E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.34</td>
<td>...</td>
</tr>
</tbody>
</table>

^AConsult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
^BGr—Grade.
^C TY—type.
^D CrMo—chromium-molybdenum.
^E For trim group definition, refer to Table 28.

### TABLE 21 Sounding Tubes, Vents, and Overflows for Freshwater, Saltwater, and Oil

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature $406^\circ F$ Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR^C B or A 53 GR B TY^E S</td>
<td>ANSI B16.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Filament wound</td>
<td>FGP^E</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial^F</td>
<td>See Table 1 and NVIC 11-86^G</td>
</tr>
<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP^E</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial^F</td>
<td>...</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: socket weld or slip-on</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>Ductile iron</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Gasketed mechanical couplings</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
<td>...</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td>...</td>
</tr>
<tr>
<td>Fittings</td>
<td>Buttweld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.9 or B16.28</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.11</td>
<td>...</td>
</tr>
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<td></td>
<td>Sleeve couplings</td>
<td>Ductile iron</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ASTM F 682 Commercial^F</td>
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<td>Adhesive bonded</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1548</td>
<td>...</td>
</tr>
<tr>
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<td>Used with gasketed mechanical</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>Trim group 4^I</td>
<td>...</td>
</tr>
<tr>
<td>Valves: gate, globe, angle, check</td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 395 A 105/A 105M</td>
<td>ANSI B16.34 Trim group 4^I</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Socket weld</td>
<td>Ductile iron</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.34 Trim group 3^I</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Brazed or threaded</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-80^F</td>
<td>Trim group 4^I</td>
</tr>
<tr>
<td></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>Trim group 3 and 4^I</td>
<td>...</td>
</tr>
</tbody>
</table>

^AWhen combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
^BConsult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
^C Gr—grade.
^D TY—type.
^E FGP—fiberglass pipe.
^F Specific Coast Guard and ABS approval required.
^G For U.S. flag vessels in addition to classification society requirements.
^H GRP—glass reinforced plastic.
^I For trim group definition, refer to Table 28.
^J MSS-SP-80 valves limited to 75% of valve design pressure.
<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Design Specification</th>
<th>Maximum Temperature</th>
<th>Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe</strong></td>
<td>Seamless or electric</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR&lt;sup&gt;C&lt;/sup&gt; B or ASTM</td>
<td>ANSI B36.10</td>
<td>240°F</td>
<td>See Table 1 and NVIC 11-86&lt;sup&gt;E&lt;/sup&gt; FGP not</td>
</tr>
<tr>
<td></td>
<td>resistance welded</td>
<td></td>
<td>A 53 TY&lt;sup&gt;D&lt;/sup&gt; S or E</td>
<td></td>
<td></td>
<td>permitted outboard of shell valve.</td>
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<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP&lt;sup&gt;E&lt;/sup&gt;</td>
<td>ASTM D 2966 GR 1</td>
<td>Commercial&lt;sup&gt;F&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FGP&lt;sup&gt;E&lt;/sup&gt;</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial&lt;sup&gt;F&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Takedown joints</strong></td>
<td>Flanges: socket weld or</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>threaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unions: socket weld or</td>
<td></td>
<td>MSS-SP-83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>threaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonding</td>
<td>GRP&lt;sup&gt;H&lt;/sup&gt;</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gasketed mechanical</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td>ASTM F 1476</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>couplings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bolting</strong></td>
<td>Bolts/bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
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<td></td>
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<tr>
<td></td>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563</td>
<td>ANSI B18.2.2</td>
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<tr>
<td><strong>Fittings</strong></td>
<td>Butt weld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socket weld or threaded</td>
<td></td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesive bonded</td>
<td>GRP&lt;sup&gt;H&lt;/sup&gt;</td>
<td>Commercial</td>
<td>Commercial&lt;sup&gt;F&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleeve coupling</td>
<td>Carbon steel</td>
<td>ASTM F 682</td>
<td>ASTM F 1548</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Used with gasketed</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mechanical couplings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Valves</strong></td>
<td>Butterfly grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td></td>
<td>Trim group 4&lt;sup&gt;I&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Valves: gate, globe, angle, check</strong></td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>ANSI B16.34</td>
<td></td>
<td>Trim group 4&lt;sup&gt;I&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbon steel</td>
<td>ASTM A 216/A 216M GR WCB</td>
<td></td>
<td></td>
<td>Trim group 3&lt;sup&gt;I&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brazed or threaded</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>ANSI B16.24</td>
<td></td>
<td>Trim group 4&lt;sup&gt;I&lt;/sup&gt;</td>
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<td></td>
<td>MSS-SP-80&lt;sup&gt;Q&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Valves: ball</strong></td>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td></td>
<td>Trim group 4&lt;sup&gt;I&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Flanged</td>
<td>Bronze</td>
<td>ASME SB61 or SB62</td>
<td>MSS-SP-72</td>
<td></td>
<td>Trim group 4&lt;sup&gt;I&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>A</sup>When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
<sup>B</sup>Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
<sup>C</sup>GR—grade.
<sup>D</sup>TY—type.
<sup>E</sup>FGP—fiberglass pipe.
<sup>F</sup>Specific Coast Guard and ABS approval required.
<sup>G</sup>For U.S. flag vessels in addition to classification society requirements.
<sup>H</sup>GRP—glass reinforced plastic.
<sup>I</sup>For trim group definition, refer to Table 28.
<sup>J</sup>MSS-SP-80 valves limited to 75% of valve design pressure.
**TABLE 23 Weather Deck Drains, Main Deck, and Above**

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded Carbon steel</td>
<td>ASTM A 106 GR B or A 53 GR B TY S or E</td>
<td>ANSI B36.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: socket welded or slip-on Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unions: socket weld Gasketed mechanical couplings Ductile iron</td>
<td>ASTM A 105/A 105M</td>
<td>MSS-SP-83</td>
<td>ASTM F 1476</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 563 GR A</td>
<td>ANSI B18.2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fittings</td>
<td>Buttweld</td>
<td>Carbon steel</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td></td>
</tr>
<tr>
<td>Socket weld</td>
<td>Ductile iron</td>
<td>ASTM A 234/A 234M GR WPB or A 105/A 105M</td>
<td>ANSI B16.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleeve couplings Used with gasketed mechanical couplings Ductile iron</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly grooved end Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td>Trim group 4</td>
<td></td>
</tr>
<tr>
<td>Valves: check</td>
<td>Flanged</td>
<td>Ductile iron</td>
<td>ASTM A 395</td>
<td>ANSI B16.34</td>
<td></td>
</tr>
<tr>
<td>Grooved end</td>
<td>Ductile iron</td>
<td>ASTM A 536</td>
<td></td>
<td>Trim group 3 and 4</td>
<td></td>
</tr>
</tbody>
</table>

^Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

^GR—grade.

^TY—type.

^For trim group definition, refer to Table 28.

**TABLE 24 Inert Gas-Generator or Uptakes to Scrubber**

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature Remarks/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Fabricated duct Alloy steel</td>
<td>ASTM A 242/A 242M TY 8</td>
<td>Commercial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: welded Alloy steel</td>
<td>ASTM A 242/A 242M TY 1</td>
<td>Commercial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts CrMoV steel</td>
<td>ASTM A 193/A 193M GR 5</td>
<td>ANSI B18.2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuts</td>
<td>Carbon steel</td>
<td>ASTM A 194/A 194M GR 4</td>
<td>ANSI B18.2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fittings</td>
<td>Fabricated duct Alloy steel</td>
<td>ASTM A 242/A 242M TY 1</td>
<td>Commercial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Sliding gate Carbon steel</td>
<td>Commercial</td>
<td></td>
<td>Trim group 3</td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly wafer or lug Ductile iron</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
<td></td>
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</tr>
</tbody>
</table>

^Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

^TY—type.

^Specific Coast Guard and ABS approval required.

^CrMoV—chromium-molybdenum-vanadium.

^GR—grade.

^CMo—carbon-molybdenum.

^For trim group definition, refer to Table 28.
### TABLE 25  Inert Gas, Scrubber to Tanks

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Maximum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Electric resistance welded</td>
<td>Carbon steel</td>
<td>ASTM A 134 GR C 285C or</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Seamles or electric</td>
<td></td>
<td>ASTM A 139/A 139M GR B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>resistance welded</td>
<td></td>
<td>B T Y C S or E</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Centrifugally cast</td>
<td>FGP</td>
<td>ASTM D 2996 GR 1</td>
<td>Commercial</td>
<td>See Table 1 and NVIC</td>
</tr>
<tr>
<td></td>
<td>Filament wound</td>
<td>FGP</td>
<td>ASTM D 2997 GR 1</td>
<td>Commercial</td>
<td>11-86 ^d</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weldneck socket</td>
<td>Carbon steel</td>
<td>ASTM A 105/105M or</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Joint or slip-on</td>
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<td>A 181/A 181M CL 60</td>
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<tr>
<td></td>
<td>Flexible couplings</td>
<td>Steel with resilient</td>
<td></td>
<td>Commercial</td>
<td></td>
</tr>
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<td></td>
<td>gaskets</td>
<td></td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flanges: adhesive bonded</td>
<td>GRP</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
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</tr>
<tr>
<td>Bolting</td>
<td>Flanges: adhesive bonded</td>
<td>GRP</td>
<td>ASTM D 4024 GR 1</td>
<td>ASTM D 4024</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Bolt or bolt studs</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
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<td>Fittings</td>
<td>Butt weld</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Socket weld</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.11</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Sleeve couplings</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
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<tr>
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<td>Adhesive bonded</td>
<td>GRP</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
<td>Trim group 8 ^d</td>
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<td>or A 105/A 105M</td>
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<td>Trim group 3 ^d</td>
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<td>Valves: gate, globe,</td>
<td>Ductile iron</td>
<td>ASTM A 216/1618M GR WCB</td>
<td>ANSI B16.34</td>
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<td></td>
<td></td>
<td>or A 105/A 105M</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Flanged</td>
<td></td>
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</tbody>
</table>

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^When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
^GR—grade.
^TY—type.
^FGP—fiberglass pipe.
^Specific Coast Guard and ABS approval required.
^For U.S. flag vessels in addition to classification society requirements.
^GRP—glass reinforced plastic.
^For trim group definition, refer to Table 28.
^MSS-SP-80 valves limited to 75% of valve design pressure.

### TABLE 26  Liquified Natural Gas Systems Including Vapor Fuel, Inert Gas, and Nitrogen Service

<table>
<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Minimum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric</td>
<td>Carbon steel</td>
<td>ASTM A 106 GR B or A 53 GR B</td>
<td>ANSI B36.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>resistance welded</td>
<td></td>
<td>B TY C S or E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weldneck socket</td>
<td>Carbon steel</td>
<td>ASTM A 105/A 105M</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Joint or slip-on</td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bolting</td>
<td>Carbon steel</td>
<td>ASTM A 307 GR B</td>
<td>ANSI B18.2.1</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fittings</td>
<td>Butt weld</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.9 or B16.28</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socket weld</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ANSI B16.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleeve coupling</td>
<td>ASTM A 234/A 234M GR WPB</td>
<td>ASTM F 682</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Butterfly wafer or lug</td>
<td>ASTM A 395</td>
<td>MSS-SP-67</td>
<td>Trim group 8 ^d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or A 105/A 105M</td>
<td></td>
<td>Trim group 3 ^d</td>
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<tr>
<td></td>
<td></td>
<td>Flanged</td>
<td></td>
<td></td>
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^Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
^GR—grade.
^TY—type.
^For trim group definition, refer to Table 28.
### TABLE 27  Liquified Natural Gas Systems Including Cargo, Inert Gas, Nitrogen, and Cargo Tank Cooldown and Warm-Up Piping Below 0°F

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<thead>
<tr>
<th>Item</th>
<th>Type/Style</th>
<th>Material</th>
<th>Material Specification</th>
<th>Design Specification</th>
<th>Minimum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Seamless or electric resistance welded</td>
<td>CRES&lt;sup&gt;B&lt;/sup&gt;</td>
<td>ASME SA312 TP&lt;sup&gt;C&lt;/sup&gt; 316L or 304L</td>
<td>ANSI B36.19</td>
<td>. . .</td>
</tr>
<tr>
<td>Takedown joints</td>
<td>Flanges: weld neck or socket weld</td>
<td>CRES</td>
<td>ASTM A 182/A 182M 316L</td>
<td>ANSI B16.5</td>
<td>. . .</td>
</tr>
<tr>
<td>Bolting</td>
<td>Bolts/bolt studs</td>
<td>CRES</td>
<td>ASTM A 320/A 320M B8, B8F, B8M, or B8C</td>
<td>ANSI B18.2.1</td>
<td>. . .</td>
</tr>
<tr>
<td>Nuts</td>
<td></td>
<td>CRES</td>
<td>ASTM A 194/A 194M 8, 8C, 8F, or 8T</td>
<td>ANSI B18.2.2</td>
<td>. . .</td>
</tr>
<tr>
<td>Fittings</td>
<td>Butt weld</td>
<td>CRES</td>
<td>ASTM A 182/A 182M 316L or 304L; or A 351/A 351M 316L or 304L; or A 351/A 351M CF3M</td>
<td>ANSI B16.9 or B16.28</td>
<td>. . .</td>
</tr>
<tr>
<td>Valves</td>
<td>Butterfly wafer or lug</td>
<td>CRES</td>
<td>ASTM A 182/A 182M 316L or 304L; or A 351/A 351M 316L or 304L; or A 351/A 351M CF3M</td>
<td>MSS-SP-67</td>
<td>Trim group 7&lt;sup&gt;E&lt;/sup&gt;</td>
</tr>
<tr>
<td>Valves: gate, globe, Flanged, butt weld, or angle, check socket weld</td>
<td>CRES</td>
<td>ASTM A 182/A 182M 316L or 304L; or A 351/A 351M 316L or 304L; or A 351/A 351M CF3M</td>
<td>ANSI B16.34</td>
<td>Trim group 7&lt;sup&gt;E&lt;/sup&gt;</td>
<td></td>
</tr>
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<sup>A</sup>Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

<sup>B</sup>CRES—corrosion resistant steel.

<sup>C</sup>TP—tubular product.

<sup>D</sup>GR—grade.

<sup>E</sup>For trim group definition, refer to Table 28.

### TABLE 28  Valve Trim Groups<sup>A</sup>

<table>
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<th>Group</th>
<th>Trim</th>
<th>Material</th>
<th>Material Specification&lt;sup&gt;B&lt;/sup&gt;</th>
<th>Remarks/Limitations</th>
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<tr>
<td>1</td>
<td>Stem</td>
<td>CRES&lt;sup&gt;C&lt;/sup&gt;</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Wedge/disk</td>
<td>CrMo&lt;sup&gt;E&lt;/sup&gt;</td>
<td>ASTM A 182/A 182M GR F11</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Seat ring</td>
<td>CrMo</td>
<td>ASTM A 182/A 182M GR F11 or ASME</td>
<td>hard-faced seat SA217 GR WGS</td>
</tr>
<tr>
<td></td>
<td>Seat, integral</td>
<td>Same as valve body</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>hard-faced seat</td>
</tr>
<tr>
<td>2</td>
<td>Stem, wedge/disk or seat ring Integral seats</td>
<td>CRES</td>
<td>Same as valve body</td>
<td>. . .</td>
</tr>
<tr>
<td>3</td>
<td>Stem, wedge/disk or seat ring Integral seats</td>
<td>CRES</td>
<td>Same as valve body</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Seat integral</td>
<td>CRES</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>hard-faced seat optional</td>
</tr>
<tr>
<td>4</td>
<td>Stem, wedge/disc or seating</td>
<td>Bronze</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Seat integral</td>
<td>Same as valve body</td>
<td>ASME SB61 or SB62</td>
<td>. . .</td>
</tr>
<tr>
<td>5</td>
<td>Stem, wedge/disk or seat ring</td>
<td>CRES</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Seat integral</td>
<td>Same as valve body</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>. . .</td>
</tr>
<tr>
<td>6</td>
<td>Stem, wedge/disc or seating</td>
<td>NCA&lt;sup&gt;A&lt;/sup&gt;</td>
<td>ASTM A 164&lt;sup&gt;C&lt;/sup&gt;</td>
<td>. . .</td>
</tr>
<tr>
<td>7</td>
<td>Stem, wedge/disc or seat ring</td>
<td>CRES</td>
<td>ASTM A 182/A 182M GR F304L or F316L or ASTM A 351/A 351M GR CF3M</td>
<td>hard-faced seat optional</td>
</tr>
<tr>
<td></td>
<td>Seat integral</td>
<td>Same as valve body</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>8</td>
<td>Stem</td>
<td>CRES</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Wedge/disk or seat ring</td>
<td>Bronze</td>
<td>ASTM A 182/A 182M GR F6a</td>
<td>. . .</td>
</tr>
<tr>
<td></td>
<td>Integral seat</td>
<td>Same as valve body</td>
<td>. . .</td>
<td>. . .</td>
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<sup>A</sup>Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

<sup>B</sup>When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.

<sup>C</sup>CRES—corrosion resistant steel.

<sup>D</sup>Gr—grade.

<sup>E</sup>CrMo—chromium-molybdenum.

<sup>F</sup>NCA—nickel copper alloy.

<sup>G</sup>Discontinued.
1. Scope

1.1 This practice establishes general human engineering design criteria for marine vessels, and systems, subsystems, and equipment contained therein. It provides a useful tool for the designer to incorporate human capabilities into a design.

1.2 The purpose of this practice is to present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the vessel system, subsystem, and equipment with the goals of effectiveness, simplicity, efficiency, reliability, and safety for operation, training, and maintenance.

1.3 This practice applies to the design of vessels, systems, subsystems, and equipment. Nothing in this practice shall be construed as limiting the selection of hardware, materials, or processes to the specific items described herein. Unless otherwise stated in specific provisions, this practice is applicable to design of vessel systems, subsystems, and equipment for use by both men and women.

1.4 Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.

1.5 This practice is not intended to be a criterion for limiting use of material already in the field in areas such as lift repetition or temperature exposure time.

1.6 Force Limits—If it is known that an item is to be used by an already established occupational specialty, for which physical qualification requirements for entry into that specialty are also established, any discrepancy between the force criteria of this practice and the physical qualification requirements shall be resolved in favor of the latter. In this event, the least stringent physical qualification requirement of all specialties which may operate, maintain, transport, supply, move, lift, or otherwise manipulate the item, in the manner being considered, is selected as a maximum design force limit.

1.7 Manufacturing Tolerances—When manufacturing tolerances are not perceptible to the user, this practice shall not be construed as preventing the use of components whose dimensions are within a normal manufacturing upper or lower limit tolerance of the dimensions specified herein.

1.8 This practice is divided into the following sections:

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

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### 2. Referenced Documents

#### 2.1 ASTM Standards:

#### 2.2 Military Specifications:
- MIL-C-25050, Colors, Aeronautical Lights and Lighting Equipment, General Requirements for

#### 2.3 Federal Standard:
- FED-STD-595 Color

#### 2.4 Military Standards:
- MIL-STD-12, Abbreviation for Use on Drawings, Specifications, Standards, and in Technical Documents
- MIL-STD-740, Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment

#### 2.5 Military Handbook:
- DOD-HDBK-743, Anthropometry of US Military Personnel

#### 2.6 Federal Regulations:
- 29 CFR 1910, Occupational Safety and Health Standards
- 46 CFR 113.25-9, U.S. Coast Guard Regulation

### 3. Terminology

#### 3.1 Definitions of Terms Specific to This Standard:

##### 3.1.1 abort—a capability that cancels all user entries in a defined transaction sequence.

##### 3.1.2 accessible—unless otherwise specified herein or where specific design values are given, an item is considered accessible only where it can be operated, manipulated, removed, or replaced by the suitably clothed and equipped user with applicable fifth and ninety-fifth percentile body dimensions. Applicable body dimensions are those dimensions that are design critical to the operation, manipulation, removal, or replacement task. For example, an adjustment control behind an access opening should be located sufficiently close to the aperture to enable a suitably clothed and equipped user with a fifth percentile depth of reach to grasp and manipulate the adjustment control, while the opening should be sufficiently large to enable passage of a similarly clothed and equipped ninety-fifth percentile hand and arm.

##### 3.1.3 advisory signal—a signal that indicates safe or normal configuration, condition of performance, operation of essential equipment, or that attracts attention and imparts information for routine action purposes.

##### 3.1.4 angle of incidence—the angle between the line of direction of anything (such as a ray of light or line of sight) striking a surface and a line perpendicular to that surface drawn to the point of contact as shown in Fig. 1.

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3.1.5 **backup**—a capability that returns a user to the last previous display in a defined transaction sequence. Also refers to the practice of preserving a second copy of files for data protection purposes.

3.1.6 **brightness**—the amount of emitted or reflected light visible to the eye.

3.1.7 **cancel**—a capability that regenerates or reinitializes the current display without processing or retaining any changes made by the user.

3.1.8 **caution signal**—a signal that alerts the operator to an impending hazardous condition requiring attention, but not necessarily immediate action.

3.1.9 **command and control system equipment**—the main mission element equipment and related ground equipment used in collecting, transmitting, processing, and displaying information for command and control.

3.1.10 **command language**—a type of dialogue in which a user composes control entries with minimal prompting by the computer.

3.1.11 **common hand tools**—items of tools found in common usage or applicable to a variety of operations or to a single operation on a variety of material. Screwdrivers, hammers, and wrenches are examples of common hand tools.

3.1.12 **control entry**—user input for sequence control, such as function key actuation, menu selection, command entry, and so forth.

3.1.13 **data**—the raw materials from which a user extracts information. Data may include numbers, words, pictures, and so forth.

3.1.14 **data display**—output of data from a computer to its users. Generally, the phrase denotes visual output, but it may be qualified to indicate a different modality, such as “auditory display.”

3.1.15 **data entry**—user input of data for computer processing and computer responses to such inputs.

3.1.16 **data field**—an area of the display screen reserved for user entry of a data item.

3.1.17 **data item**—a set of characters of fixed or variable length that forms a single unit of data. Examples of a data item might be a person’s name or a zip code. Data items may be entered by a user or may be supplied by the computer.

3.1.18 **data protection**—functional capabilities that guard against unauthorized data access and tampering, user errors, and computer failure.

3.1.19 **4a decibel (dB)**—sound level, measured between acoustic signals, equal to ten times the common logarithm of the ratio of the two levels.

3.1.20 **4a dBA**—the sound level measured through the A-weighing network of a sound level meter.

3.1.21 **de-emphasis**—the inverse of preemphasis, used for the purpose of restoring original vowel-consonant amplitude relationships in preemphasized speech; primarily useful in maintaining the “natural” sound quality. (See 3.1.56)

3.1.22 **default value**—a predetermined, frequently used value for a data field or control entry, intended to reduce required user entry actions.

3.1.23 **dialogue**—a structured series of interchanges between a user and a computer terminal. Dialogues can be computer initiated, for example, question and answer, or user initiated, for example, command languages.

3.1.24 **dichotic**—the condition in which the sound stimulus presented at one ear differs from the sound stimulus presented at the other ear. The stimulus may differ in sound pressure, frequency, phase, time, duration, or bandwidth.

3.1.25 **display format**—the organization of different types of data in a display, including information about the data such as labels, and other user guidance such as prompts, error messages, and so forth.

3.1.26 **effective temperature (ET)**—a single value combining the effect of temperature, humidity, and air movement on the sensation of warmth or cold felt by the human body. The numerical value is that of the temperature of still, saturated air, that would induce an identical sensation.

3.1.27 **emergency**—a condition of danger that requires immediate action.

3.1.28 **emergency alarm**—an alarm that indicates that danger exists and that immediate action must be taken. They include the general emergency alarm, fire alarms, those alarms giving warning of personnel hazard; including fire-extinguishing medium alarm, power-operated sliding watertight door closure alarm, and fire detection alarm.

3.1.29 **enter**—an explicit user action that effects computer processing of user entries. For example, after typing a series of numbers, a user might press an ENTER key that will add them to a database, subject to data validation.

3.1.30 **equipment**—general term designating any item or group of items.

3.1.31 **equipment failure**—the cessation of the ability to meet the minimum performance requirements of the equipment specifications. Further, equipment failure shall imply that the minimum specified performance cannot be restored through permissible readjustment of operator controls.

3.1.32 **facilities**—a physical plant, such as real estate and improvements thereto, including building and equipment, which provides the means for assisting or making easier the performance of a system function. The facilities to which this practice apply are those in which personnel perform system operational or maintenance duties.

3.1.33 **fail-safe design**—a design that, upon failure or malfunction of a component, subsystem, or system, automatically reverts to a predetermined design state of least critical consequence.

3.1.34 **field**—see 3.1.16.

3.1.35 **file**—a collection of data, treated as a single unit, that is stored in a computer.

3.1.36 **function key**—a key whose actuation will effect a control entry.

3.1.37 **help**—a capability that displays information upon user request for on-line guidance. HELP may inform a user generally about system capabilities or may provide more specific guidance in information-handling transactions.

3.1.38 **highlighting**—emphasizing displayed data or format features in some way, for example, through the use of underlining, bolding, or inverse video.
3.1.39 human engineering design criteria—the summation of available knowledge that defines the nature and limits of human capabilities as they relate to the checkout, operation, maintenance, or control of systems or equipment, to achieve optimum compatibility between equipment and human performance.

3.1.40 information—organized data that users need to perform their tasks successfully. Information serves as an answer to a user’s questions about data. It is used here to refer to the effective assimilation of data by a user.

3.1.41 interrupt—stopping an ongoing transaction to redirect the course of the processing. Examples of interrupt options are ABORT, BACKUP, CANCEL, and RESTART.

3.1.42 legibility—the ability to see and identify the alphanumeric characters, symbols, or other visual information on a display.

3.1.43 luminance contrast—the contrast between background and a figure equals the absolute difference between the higher luminance, \( L_1 \), and the lower luminance, \( L_2 \), divided by the higher luminance; that is, \( C = (L_1 - L_2)/L_1 \). Conversions to the other contrast formulae are as follows:

\[
\begin{align*}
L_1 & \quad L_2 & \quad L_1L_2 & \quad L_1-L_2 & \quad L_1+L_2 & \quad L_1/L_2 \\
100 & \quad 150 & \quad 1.0 & \quad 0.50 & \quad 0.33 & \quad 2.0 \\
100 & \quad 25 & \quad 3.0 & \quad 0.75 & \quad 0.60 & \quad 4.0 \\
100 & \quad 10 & \quad 9.0 & \quad 0.90 & \quad 0.82 & \quad 10.0 \\
\end{align*}
\]

where:

\( L_1 \) = image or subject luminance and

\( L_n \) = non-image or background luminance.

3.1.44 luminance ratio (LR)—the difference in luminance between the target subject and the surrounding field or background. For projection systems, the luminance ratio is equal to the light output of a projector (measured with no film in the projector) reflected off the screen (image luminance) divided by all the light falling on the screen (measured from the greatest viewing angle) other than that actually forming the image (non-image or background); as follows:

\[
LR = \frac{L_1}{L_n}
\]

3.1.45 macro—the capability to allow the user to assign a single name or function key to a defined series of commands for use with subsequent command entry. Sometimes called “smartkey.” Examples of use are storage of addresses or a single name or function key to a defined series of commands.

3.1.46 maintainability design—design considerations directed toward achieving those combined characteristics of the equipment and human beings that will enable the accomplishment of necessary maintenance quickly, safely, accurately, and effectively with minimum requirements for personnel, skills, special tools, and cost.

3.1.47 master caution (warning) signal—a signal that indicates that one or more caution (warning) lights has been actuated.

3.1.48 menu selection—a type of dialogue in which the user selects one item out of a list of displayed alternatives, whether the selection is by pointing, by entry of an associated option code, or by actuation of an assigned function key.

3.1.49 metric equivalents, abbreviations, and prefixes—Table 1 has been used herein to reflect the International System of Units (SI).

3.1.50 noise-cancelling (microphone)—a feature that reduces the masking effect of ambient noise upon speech impressed on a microphone, usually by providing equal access of the ambient noise to both surfaces of a diaphragm to achieve approximate equilibrium, effectively causing the noise to cancel itself out. Since the talker’s own voice output impinges on only one side of the microphone diaphragm, the talker’s signals are not subject to this cancellation, and are transmitted more favorably than if both ambient noise and speech fell simultaneously upon one face of the diaphragm.

3.1.51 nuclear, biological, chemical (NBC), and other contaminated environment survivability—NBC survivability includes both the instantaneous, cumulative, and residual effects of NBC weapons or environmental contamination upon a system, including its personnel. NBC or other environmental survivability describes the capability of a system to withstand the NBC environment, including decontamination, without losing the ability to accomplish its mission. For any system to be considered survivable in a contaminated environment, it must have at least three essential characteristics: decontaminability, hardness, and compatibility.

decontaminability—the ability of a system to be rapidly decontaminated to reduce the hazard to personnel operating.

### TABLE 1 Metric Equivalents, Abbreviations, and Prefixes

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<tr>
<td>nano n</td>
<td>10⁻⁹</td>
</tr>
<tr>
<td>micro µ</td>
<td>10⁻⁶</td>
</tr>
<tr>
<td>milli m</td>
<td>10⁻³</td>
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</table>

A more complete listing and discussion may be found in IEEE/ASTM.
maintaining, and resupplying it. 

hardness—the ability of a system to withstand the material damaging effects of NBC contamination and any decontamination agents and procedures required to remove it. compatibility—the ability of a system to be effectively operated, maintained, and resupplied by persons wearing the full NBC or other protective ensemble.

3.1.52 page—for this standard, the data appearing at one time on a single display screen.

3.1.53 panel—the front face of an assembly, normally used for mounting controls and displays.

3.1.54 panning—an orientation for display framing in which a user conceives of the display as moving over a fixed array of data. The opposite of scrolling.

3.1.55 peak-clipping (of speech signals)—a technique for controlling amplitude relationships in speech by limiting the instantaneous peak amplitudes to improve intelligibility of speech, usually followed by amplification of the signal to increase the amplitude of the clipped peaks to their original level, with proportional increase of the weaker speech sounds.

3.1.56 preemphasis—systematic distortion of the speech spectrum to improve intelligibility of speech sound by attenuating the low-frequency components of vowels (relatively unimportant for intelligibility) and proportionately increasing the amplitude of high-frequency vowel components and consonants (highly important for intelligible speech transmission).

3.1.57 primary alarm (essential alarm)—an alarm that indicates a condition that requires prompt attention to prevent an emergency condition. They include machinery alarms, control fault alarms, alarms indicating faults in emergency or primary (essential) alarm(s) or detection systems or failure of their normal power supplies, steering gear alarms, bilge alarms, engineer’s alarms, and personnel alarms.

3.1.58 prompt—an indicator provided by the computer that alerts the user that the computer is ready, data should be entered, and so forth.

3.1.59 query language—a language that allows users to compose control entries for displaying specified data from a database.

3.1.60 question and answer—a type of dialogue in which the computer displays questions, one at a time, for a user to answer.

3.1.61 readability—the ability to understand the message imparted by printed material, characters, numbers, or other visual information from a visual display.

3.1.62 remote-handling system—the equipment (for example, manipulators, viewing devices, and other aids) that permits personnel to extend their capabilities into remote environments.

3.1.63 scrolling—an orientation for display framing in which the user conceives of data as moving behind a fixed display frame. The opposite of panning.

3.1.64 seat reference point (SRP)—the point at which the center line of the seat back surface (depressed) and seat bottom surface (depressed) intersect. When the seat is positioned at the midpoint of the adjustment range(s), this intersection point is called the neutral seat reference point.

3.1.65 signals—a secondary, nonessential, advisory, or call indication. (Call is a request for contact, assistance, or action from one location to another.)

3.1.66 sound pressure level (SPL)—the pressure of an acoustic wave; usually expressed in decibels (dB), equal to 20 times the logarithm to the base 10 of the ratio of the effective root-mean-square (rms) pressure of this sound to the reference pressure, as follows:

$$\text{SPL} = 20 \log_{10} \frac{P}{20 \mu \text{Pa}}$$

where:

$$P = \text{the effective (rms) sound pressure in micropascals (µPa) or micronewtons per square metre (µN/M}^2\text{).} (20 \mu \text{Pa} = 20 \mu\text{N/M}^2 = 0.0002 \text{ microbar} = 0.0002 \text{ dynes/cm}^2\text{.)}$$

3.1.67 source documents—user’s documents, which are a source of data eventually processed by the computer program, such as target lists, supply codes, parts lists, maintenance forms, bills of lading, and so forth.

3.1.68 spatial relationship—the placement of controls, displays, and their related equipment so that it is visually obvious to an operator or maintainer that all components of a particular system are related. Further, when controls and displays are used for identical equipments or systems located in different parts of the same compartment, or in different compartments, the controls and displays shall be placed in the same location in respect to the equipments or systems at each installation. Consoles and overall work stations shall be designed and placed so the individual controls and displays on the consoles or work stations are arranged, as viewed by the operator facing the console or work station, in the same spatial arrangement as is the actual equipment being controlled or monitored at the console or work station.

3.1.69 special tools—tools not listed in the Federal Supply Catalog or meet the requirements of 3.1.75.

3.1.70 speech intelligibility—a measure of the percent of words, phrases, or sentences correctly understood over a given speech communication system in a given noise situation. It may be measured, when complying with this practice, by using either the phonetically balanced Monosyllabic Word Intelligibility Test or the Modified Rhyme Test (MRT), or may be calculated by the Articulation Index (AI).

3.1.71 speech interference level (SIL)—a measure of the effectiveness of noise in masking speech, defined as the arithmetic average of the same pressure levels of the interfering noise (in decibels re 20 µPa) in the four-octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel.

3.1.72 speech signal processing—the modification of the electrical signal representing speech to enhance the capability of a speech communications channel. Some examples are simple analog processing, Automatic Gain Control (AGC), frequency shaping, peak clipping, and syllabic compression.

3.1.73 speech spectrum—a segment of the range of audible frequencies containing the sounds of speech; defined as approximately the range from 80 to 8000 Hz.
3.1.74 **speech-to-noise ratio (peak speech to rms noise)**—
the ratio between the arithmetic mean of peak amplitudes of speech and the root-mean-square (rms) amplitude of background noise.

3.1.75 **standard tools**—standard tools (normally hand tools) used for the assembly, disassembly, inspection, servicing, repair, and maintenance of the equipment, and which are manufactured by two or more recognized tool manufacturing companies and are listed in those companies’ catalogs.

3.1.76 **string**—in the user’s context, a word, phrase, or number (string of characters) in the text or file. Normally used in the context of causing the computer to search for, find, or replace a desired “string.”

3.1.77 **text entry**—initial entry and subsequent editing of textual material, typified by messages.

3.1.78 **transaction**—an action by a user followed by a response from the computer. The term is used here to represent the smallest functional “molecule” of user-computer interaction.

3.1.79 **transillumination**—light passed through, rather than reflected off, an element to be viewed, for example, illumination used on console panels or indicators using edge or backlighting techniques on clear, translucent, fluorescent, or sandwich-type plastic materials.

3.1.80 **visibility**—the ability to see a visual display from its surrounding background.

3.1.81 **warning signal**—a signal that alerts the operator to a dangerous condition requiring immediate action.

3.1.82 **wet bulb globe temperature (WBGT)**—an index of the stress incorporating, as a major element, the evaporative cooling available to a natural wet bulb thermometer and calculated as follows:

\[
WBGT = 0.7TWB_{np} + 0.2T_g + 0.1T_a
\]  

where:

- \(TWB_{np}\) = nonpsychometric (np) wet-bulb (WB) temperature,
- \(T_g\) = temperature at interior center of a 15.2-cm (6-in.) black globe, and
- \(T_a\) = nonpsychometric, but shaded, dry bulb (air) temperature.

—In the absence of a radiant heat source (solar, engine, furnace, and so forth), a modified wet-dry (WD85) index shall be used where:

\[
WD85 = 0.85TWB_{np} + 0.15T_a
\]

4. **Significance and Use**

4.1 **Objectives**—Vessels, systems, and equipment shall provide work environments that foster effective procedures, work patterns, and personnel safety and health, and that minimize factors which degrade human performance or increase error. Design shall be such that operator workload, accuracy, time constraint, mental processing, and communication requirements do not exceed the operator’s physical or mental capacities. Design shall also minimize personnel and training requirements within the limits of time, cost, and performance trade-offs.

4.2 **Standardization**—Controls, displays, marking, coding, labeling, and arrangement schemes (equipment and panel layout) shall be uniform for common functions of all equipment. One criterion for selecting off-the-shelf commercial or government equipment shall be the degree to which the equipment conforms to this practice. Where off-the-shelf equipment requires modification to interface with other equipment, the modification shall be designed to comply with the criteria herein. Redesign of off-the-shelf equipment shall have the approval of the procuring activity.

4.3 **Function Allocation**—The design shall reflect allocation of functions to personnel, equipment, and personnel-equipment combinations to achieve the following:

4.3.1 **Required sensitivity, precision, time, and safety.**

4.3.2 **Required reliability of system performance.**

4.3.3 **Minimum number and level of skills of personnel required to operate and maintain the system.**

4.3.4 **Required performance in a cost-effective manner.**

4.4 **Human Engineering Design**—The design of vessels, systems, and equipment shall include the human engineering, life support, and biomedical design criteria, when applicable, contained in this practice to provide the following:

4.4.1 **Satisfactory atmospheric conditions including composition, pressure, temperature, and humidity, and also safeguards against uncontrolled variability beyond the limits contained herein.**

4.4.2 **Acceptable limits of acoustic noise, vibration, acceleration, shock, blast, impact forces, and safeguards against uncontrolled variability beyond the safe limits defined in this practice.**

4.4.3 **Protection from thermal, toxicological, radiological, mechanical, electrical, electromagnetic, pyrotechnic, visual, and other hazards.**

4.4.4 **Space for personnel, their equipment, and free volume for the movements and activities they are required to perform during operation and maintenance tasks under both normal and emergency conditions.**

4.4.5 **Physical, visual, auditory, and other communication links between personnel, and between personnel and their equipment, under both normal and emergency conditions.**

4.4.6 **Efficient arrangement of operation and maintenance workplaces, equipment, controls, and displays.**

4.4.7 **Natural or artificial illumination for the performance of operation, control, training, and maintenance.**

4.4.8 **Safe and adequate passageways, hatches, ladders, stairways, platforms, inclines, and other provisions for ingress, egress, and passage under normal, adverse, and emergency conditions.**

4.4.9 **Provision of acceptable personnel accommodations including body support and restraint, seating, rest, and sustenance, that is, food, water, and waste management.**

4.4.10 **Provision of nonrestrictive personal life support and protective equipment and clothing.**

4.4.11 **Provisions for minimizing psychophysiological stress effects of mission duration and fatigue.**

4.4.12 **Design features to ensure rapidity, safety, ease, and economy of operation and maintenance in normal, adverse, and emergency maintenance environments.**
4.4.13 Satisfactory remote handling provisions and tools.
4.4.14 Emergency systems for contingency management, escape, survival, and rescue.
4.4.15 Compatibility of the design, location, and layout of controls, displays, workspaces, maintenance accesses, storage provisions, and passenger compartments with the clothing and personal equipment (C/PE) to be worn by personnel operating, riding in, or maintaining all systems or equipment. Task allocation and control movements shall be compatible with restrictions imposed on human performance by C/PE.
4.4.16 Compatibility of control/display interfaces and procedures with human information processing capability, decision-making effectiveness, and the limits of short-term memory, long-term memory, and computation skill.
4.4.17 Immediate, accurate, and pertinent feedback to the operator of equipment or system performance after each control movement or other action taken by the operator.
4.5 Fail-Safe Design—A fail-safe design shall be provided in those areas in which failure can disable a vital system or cause catastrophe through damage to equipment, injury to personnel, or inadvertent operation of critical equipment.
4.6 Simplicity of Design—The equipment shall represent the simplest design consistent with functional requirements and expected service conditions. Where practical, it shall be capable of operation, maintenance, and repair in its operational environment by personnel with a minimum of training.
4.7 Interaction—The design of the system shall reflect the interaction requirements of crew-served equipment.
4.8 Safety—Design shall reflect applicable system and personnel safety factors, including minimization of potential human error in the operation and maintenance of the system, particularly under the conditions of stress.
4.9 Ruggedness—Systems and equipment shall be sufficiently rugged to withstand handling during operation, maintenance, supply, and transport within the environmental limits specified for those conditions in the applicable hardware or system specification.
4.10 Design for NBC and Other Contaminated Environment Survivability—As applicable, equipment design shall be compatible with NBC and other contaminated environment protection and shall permit performance of mission-essential operations, communications, maintenance, resupply, and decontamination tasks by suitably clothed, trained, and acclimatized personnel for the survival periods and NBC or other environments required by the system. Equipment design shall also facilitate contaminated environment hardness surveillance and shall minimize susceptibility to reduction of inherent contaminated environment hardness as a result of errors or damage induced by maintenance or operator personnel.
4.10.1 NBC or other contaminated environments hardness shall be easily verifiable by maintenance personnel before and after maintenance actions (hardness surveillance).
4.10.2 NBC or other contaminated environments hardness shall not be degraded when routine (scheduled) and corrective (unscheduled) maintenance are performed.
4.10.3 Maintenance of the equipment’s inherent NBC or other contaminated environments hardness shall not be depen- dent on maintenance personnel expertise and critical alignments/maintenance actions.
4.11 Design for Electromagnetic Pulse (EMP) Hardening—As applicable, equipment design shall be compatible with EMP-hardening requirements, including personal accommodations such as EMP-hardened electrical power outlets and antenna lead-ins within EMP-hardened facilities or spaces. Access shall be provided to EMP-hardened facilities or spaces without the need to open doors or hatches which form part of an electromagnetic barrier protecting the space. Items such as surge arrestors, terminal protection devices, and filters, which form part of an electromagnetic barrier for protection against EMP effects, shall be accessible.

5. Control/Display Integration

5.1 Control/Display Relationship—The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator. Controls shall be located adjacent to (normally under or to the right of) their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.
5.2 Control/Display/Equipment Relationships—Where controls and displays (such as a motor controller and gage board) are associated with a specific piece of equipment (for example, a pump, filter, heater, and so forth) and the controls or displays are located for local operation of the equipment, they shall be located above, or immediately adjacent to, the equipment so that it is visually obvious that all of the components are functionally related. Where other design considerations or where a deliberate choice is made to place the controls and displays remote from the equipment which precludes this preferred location, the controls and displays shall be mounted in such a manner that the relationship of location of the controls and displays matches the arrangement of the equipment to which they belong. Controls and displays used on identical systems located in different locations in the same compartment, or in different compartments, shall be located in the same spatial relationship to the equipment in each compartment. Figs. 2-5 illustrate these principles.
5.3 Design—Control-display relationships shall be apparent through proximity, similarity of groupings, coding, framing, labeling, and similar techniques.
5.4 Complexity and Precision—The complexity and precision required of control manipulation and display monitoring shall be consistent with the precision required of the system.
Control/display complexity and precision shall not exceed the capability of the operator (in terms of discrimination of display detail) or exceed the operator's manipulative capability under the dynamic conditions and environment (in terms of manual dexterity, coordination, or reaction time) in which human performance is expected to occur.

5.5 Feedback—Feedback on control response adequacy shall be provided as rapidly as possible. For keyboards, feedback shall be provided to the operator before entry to ensure that the keyed entry is, in fact, errorless and the one that the operator desires to enter.

5.6 Illumination—Adjustable illumination shall be provided for visual displays, including display, control, and panel labels and critical markings, that must be read at night or under darkened conditions.

5.7 Simultaneous Access—If more than one crew member must have simultaneous access to a particular group of controls or displays to ensure proper functioning of a system or subsystem, the operator assigned to control and monitor a particular function or group of related functions shall have physical and visual access to all controls, displays, and communication capability necessary to perform assigned tasks adequately.

5.8 Position Relationships:

5.8.1 Functional Grouping—Functionally related controls and displays shall be located in proximity to one another and arranged in functional groups, for example, power, status, test.

5.8.2 Functional Group Arrangement:

5.8.2.1 Sequence—Functional groups of controls and displays shall be located to provide for left-to-right (preferred) or top-to-bottom order of use, or both.

5.8.2.2 Access—Providing that the integrity of grouping by function and sequence is not compromised, the more frequently used groups and the most important groups shall be located in areas of easiest access. Control-display groups required solely for maintenance purposes may be located in positions providing a lesser degree of access relative to operating groups.

5.8.2.3 Functional Group Marking—Functional groups may be set apart by outlining with contrasting lines that completely encompass the groups. Color numbers in this paragraph are in accordance with FED-STD-595. Where such coding is specified by the procuring activity, and where gray panels are used, noncritical functional groups (those not associated with emergency operations) shall be outlined with a
1.5-mm (1/16-in.) black border (27038), and those involving emergency or extremely critical operations shall be outlined with a 5-mm (3/16-in.) red border (21136). As an alternate method, contrasting color pads or patches may be used to designate both critical and noncritical functional areas, subject to prior approval by the procuring activity. When red compartment lighting is used, an orange-yellow (23538) and black (27038) striped border shall be used to outline functional groups involving emergency (hazardous or potentially hazardous) conditions requiring immediate attention) or extremely critical operations.

5.8.4.4 Consistency—Location of recurring functional groups and individual items shall be similar from panel to panel. Mirror image arrangements shall be used only with the approval of the procuring activity.

5.8.3 Location and Arrangement—Whenever an operator must use a large number of controls and displays, their location and arrangement shall be designed to aid in determining which controls are used with which displays, which equipment component each control affects, and which equipment component each display describes.

5.8.4 Arrangement Within Groups—Controls and displays within functional groups shall be located according to operational sequence or function, or both.

5.8.4.1 Left-to-Right Arrangement—If there is more than one row of displays, and their corresponding controls cannot be located under each display, or placed in the same row arrangement under the displays as the displays are arranged, then the controls shall be located as shown in Fig. 6.

5.8.4.2 Vertical and Horizontal Arrays—If a horizontal row of displays must be associated with a vertical column of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array, and so forth. However, this type of arrangement shall be avoided whenever possible.

5.8.4.3 Simultaneous Use—A visual display that must be monitored concurrently with manipulation of a related control shall be located so that the operator is not required to observe the display from an extreme visual angle and thus introduce the possibility of parallax error.

5.8.4.4 Multiple Displays—When the manipulation of one control requires the reading of several displays, the control shall be placed as near as possible to the related displays and preferably beneath the middle of the displays, but not to obscure displays when manipulating the control.

5.8.4.5 Combined Control—When separate displays are affected by a combined control (for example, concentrically ganged knobs), the display shall be arranged from left to right with the combined control underneath the center of the displays, but not to obscure displays when manipulating controls.

5.8.4.6 Separate Panels—When related controls and displays must be located on separate panels and both panels are mounted at approximately the same angle relative to the operator, the control positions on one panel shall correspond to the associated display positions on the other panel. The two panels shall not be mounted facing each other.

5.8.4.7 Component Groups—When a group of equipment components has the same function, the related control and display positions shall be oriented to correspond to those of the controlled and monitored components. (For example, the position of propulsion engine controls shall be oriented as if the operator faces the normal direction of vessel movement.)

5.8.4.8 Emergency Use—Emergency displays and controls are those associated with a hazardous or potentially hazardous condition that requires immediate action to prevent injury to the crew or damage to the ship. They shall be located where they can be seen and reached with minimum delay (for example, warning lights within a 30° cone about the operator’s normal line of sight; emergency control close to its related warning display or the nearest available hand in its nominal operating position).

5.9 Movement Relationships:

5.9.1 Lack of Ambiguity—Display indicators shall clearly and unambiguously direct and guide the appropriate control response. The response of a display to control movements shall be consistent, predictable, and compatible with the operator’s expectations.

5.9.2 Time Lag—The time lag between the response of a system to a control input and the display presentation of the response shall be minimized, consistent with safe and efficient system operation.

5.9.3 Moving Pointer Circular Scales—Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the reading.

5.9.4 Moving Pointer Linear Scales—Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a movement up or to the right for horizontal and vertical scale pointers and an increase in the magnitude of the reading.

5.9.5 Fixed Pointer Circular Scale—Displays with moving scales and fixed pointers or cursers shall be avoided. When circular fixed-pointer, moving-scale indicators are necessary, clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall normally produce a counterclockwise movement of the scale and an increase in the magnitude of the reading.

![FIG. 6 Preferred and Acceptable Alternatives for Multiple Row/Column Display and Control Arrangement](image-url)

<table>
<thead>
<tr>
<th>DISPLAYS</th>
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<tr>
<th>PREFERRED CONTROL ARR.</th>
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<td>[Diagram of preferred arrangement]</td>
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<tr>
<th>ACCEPTABLE CONTROL ARR.</th>
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<tr>
<td>[Diagram of acceptable arrangement]</td>
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</table>
5.9.6 Fixed Pointer Linear Scale—When use of vertical or horizontal fixed pointer, moving-scale indicators is necessary, clockwise movement of an associated rotary control or movement of a linear control forward, up, or to the right shall normally produce a movement of the scale down or to the left and an increase in the magnitude of the reading.

5.9.7 Direct Linkage—When there is a direct linkage between control and display (for example, radio frequency selector and station pointer), a rotary control shall be used if the indicator moves through an arc of more than 180°. If the indicator moves through an arc of less than 180° a linear control may be used, provided that the path of control movement parallels the average path of the indicator movement and that the indicator and control move in the same relative direction.

5.9.8 Common Plane—Controls shall be selected so that the direction of movement of the control will be consistent with the related movement of an associated display, equipment component, or vessel.

5.9.9 Parallel Movement—Direction-of-motion relationships shall be adhered to when control and display are parallel in line of movement.

5.9.10 Labeling—When control-display relationships specified herein cannot be adhered to, controls shall be clearly labeled (in accordance with Section 27) to indicate the direction of control movement required.

5.9.11 Movement Direction—When a rotary control and a linear display are in the same plane, the part of the control adjacent to the display shall move in the same direction as the moving part of the display.

5.10 Control Display Movement Ratio:

5.10.1 Minimization of Time—Control display ratios for continuous adjustment controls shall minimize the total time required to make the desired control movement (slowing time plus fine adjusting time), consistent with display size, tolerance requirements, viewing distance, and time required.

5.10.2 Range of Display Movement—When a wide range of display element movement is required, small movement of the control shall yield a large movement of the display element. When a small range of display movement is required, a large movement of the control shall result in small movement of the display, consistent with final accuracy required.

5.10.3 Knob, Coarse Setting—When a knob is provided for making coarse display element settings on linear scales (0.4- to 2.5-mm (0.016- to 0.100-in.) tolerance), an 2.5-mm (0.016- to 0.100-in.) tolerance), an approximately 25 to 50 mm (1 to 2 in.) of display element movement shall be provided for one complete turn of the knob.

5.10.4 Knob, Fine Setting—For fine setting on linear scales (0.2- to 0.4-mm (0.008- to 0.016-in.) tolerance), a 25 to 50 mm (1 to 2 in.) of display element movement shall be provided for one complete turn of the knob.

5.10.5 Bracketing—When bracketing is used to locate a maximum or minimum rather than a specific value (for example, as in tuning a transmitter), the control knob shall swing through an arc of not less than 175 mrad (10°) nor more than 525 mrad (30°) either side of the target value to make the peak or dip associated with that value clearly noticeable.

5.10.6 Lever, Coarse Setting—When a lever is provided for coarse settings (0.4- to 2.5-mm (0.016- to 0.100-in.) tolerance), one unit of display element movement shall be used to three units of lever movement.

5.10.7 Lever, Two-Dimensional Setting—When a lever is provided to make settings in two dimensions to coarse tolerances (2.5 mm (0.100 in.), one unit of display element movement shall be used to two and one-half units of lever movement.

5.10.8 Counters—When counters are provided, the control-display ratio shall be such that one revolution of the knob produces approximately 50 counts (that is, the right hand drum rotates 5 times).

6. Visual Displays, General Information

6.1 General—Visual displays shall be used to provide the operator with a clear indication of equipment or system conditions for operation under any condition commensurate with the operational and maintenance philosophy of the system under design.

6.2 Alerting/Warning—An alerting/warning display shall provide the operator with a greater probability of detecting the triggering condition than normal observation would provide in the absence of the display.

6.3 Display Illumination and Light Distribution:

6.3.1 Display Illumination:

6.3.1.1 Normal—When maximum dark adaptation is not required, low-brightness white light (preferably integral and adjustable as appropriate) shall be used; however, when complete dark adaptation is required, low-level illumination shall be accomplished by use of gray filter sleeves over the lamps. The white light transmittance through the sleeves shall be either 5.0, 2.5, or 1.0 %.

6.3.1.2 Night Vision Device Compatibility—When night vision devices will be worn or used by the operator(s), display illumination color shall be low-density blue-green light (incandescent filament through a high-pass filter with a 600-nm cutoff). The color selected shall provide the operator(s) with the capability to obtain required display information rapidly and accurately with unaided eye vision or via viewing with the night vision device. The color selected shall also provide the operator(s) with the ability to obtain required display information rapidly and accurately during any daylight condition. The lighting shall be continuously variable to the full OFF position. In the OFF position, no current shall flow through the lamps.

6.3.1.3 Field Use Panel Dimming—When control or annunciator panels will be viewed by personnel out of doors at night, maximum panel illumination shall be provided when a dimming rotary control is at its extreme clockwise rotation. Maximum illumination is that in accordance with 32.9. No current shall be provided to luminaries at extreme counter-clockwise orientation of a dimming control. Panel light levels shall be continuously variable from 0.1 cd/m² (0.03 fl) near OFF to 3.5 cd/m² (1 fl) at 50 % of clockwise rotation.

6.3.2 Light Distribution—Where multiple displays are grouped together, lighting shall be balanced across the instrument panel such that the mean indicator luminances of any two instruments shall not differ by more than 33 % across the range of full ON to full OFF. Light distribution shall be sufficiently
uniform within an integrally illuminated instrument such that
the ratio of standard deviation of indicator element luminances
to mean indicator luminance shall not be more than 0.25, using
eight or more equally spaced test measurements.

6.3.3 Contrast—Sufficient contrast shall be provided be-
tween all displayed information and the display background to
ensure that the required information can be perceived by the
operator under all expected lighting conditions.

6.4 Information:

6.4.1 Content—The information displayed to an operator
shall allow the operator to perform the intended mission, but
shall be limited to that which is necessary to perform specific
actions or to make decisions.

6.4.2 Precision—Information shall be displayed only within
the limits and precision required for specified operator actions
or decisions.

6.4.3 Format—Information shall be presented to the opera-
tor in a directly usable form. Requirements for transposing,
computing, interpolating, or mentally translating into other
units shall be prohibited.

6.4.4 Redundancy—Redundancy in the display of informa-
tion to a single operator shall be avoided unless it is required
to achieve specified reliability.

6.4.5 Combining Operator/Maintainer Information—
Operator and maintainer information shall not be combined in
a single display unless the information content and format are
well suited to, and time is compatible for, both users.

6.4.6 Display Failure Clarity—A method shall be provided
to determine if a display or circuit has failed.

6.4.7 Display Circuit Failure—Failure of the display circuit
shall not cause a failure in the equipment associated with the
display.

6.4.8 Unrelated Markings—Trademarks and company
names or other similar markings not related to the panel
function shall not be displayed on the panel face or on the
displays.

6.4.9 Duration—For signals or displays that frequently or
consistently change their outputs, the information displayed
shall have durations of sufficient length to be reliably detected
under expected operator workload and operational environ-
ment.

6.4.10 Timeliness—Displays, such as cathode ray tube dis-
plays, requiring refreshed information shall be updated in a
synchronous manner, and be refreshed to a degree of timeliness
required by personnel in the normal operating or servicing
mode.

6.4.11 Advisory and Alerting—Displays such as multifunc-
tion displays, cathode ray tube displays, and other visual
display devices displaying simultaneous and integrated informa-
tion shall advise or alert operating personnel to information
that becomes critical within the display.

6.4.12 NBC Contamination—As applicable, display charac-
teristics (for example, clarity, legibility) shall be compatible
with viewing while wearing an NBC or other protective mask.
Displays or indicators that show the presence of NBC or other
environmental contamination agents shall also show when such
agent concentrations decrease to safe levels.

6.4.13 Numeric Digital Displays—Numeric digital displays
shall not be used as the only display of information when
trends in display change or perception of a display pattern is
required of the operator. Numeric digital displays shall not be
used when rapid or slow digital display rates inhibit perception
of the display.

7. Location and Arrangement of Visual Displays

7.1 Location—Displays, including sight fill tubes on tanks,
shall be located and designed so that they may be read to the
degree of accuracy required by personnel in the normal
operating or servicing positions without requiring the operator
to assume an uncomfortable, awkward, or unsafe position.
Dual gages providing an IN and OUT reading (that is, suction
and discharge, voltage in and out, and so forth) shall be
arranged so that the gage with the IN reading is on the left
(preferred) or top, and the gage with the OUT reading is on the
right (preferred) or bottom, unless the IN and OUT displays are
a part of a system mimic that does not permit this arrangement.

7.2 Access—Visual displays shall be visually accessible
from the normal work position without requiring the operator
to stand on equipment components, handrails, wireways or
wireway supports, or nearby pipes (especially if they are
insulated). Flashlights or other special equipment shall not be
required to read the display. No display shall require the
removal of a cover (that is, sheathing, deck plate, and so forth)
or any other component to be visible, unless the display is
noncritical and a clearly marked quick access door is provided.
Where possible, the access door shall be of transparent
material. Light-emitting diodes (LEDs) used on PC boards
inside consoles for calibration or troubleshooting shall be
visible from the maintainer’s normal work position once the
console doors or maintenance access openings are open.

7.3 Orientation—Displays, such as thermometers, pressure
gages, and so forth, that are attached directly to a pipe shall be
mounted so they are read upright, or turned no more than 90°,
from the upright position. Displays located immediately adja-
cent to walkways shall not be located lower than 460 mm (18
in.) above the deck to prevent them from being kicked and
broken, unless the display face is protected by a nonbreakable
transparent material. Armored sight gages shall be oriented so
the sight gage is directly visible from the normal work position.

7.4 Reflection—Displays shall be constructed, arranged, and
mounted to prevent reduction of information transfer as a result
of the reflection of the ambient illumination from the display
cover. Reflection of instruments and consoles in windows and
other reflective enclosures shall be avoided. If necessary,
techniques (such as shields and filters) shall be used to ensure
that the system performance will not be degraded. Sight gages
that contain clear liquid shall have a color backing so as to
provide a color contrast between the liquid and the color
backing to make the liquid more visible in the gage.

7.5 Vibration—Vibration of visual display shall not degrade
user performance below the level required for mission accom-
plishment (see 32.13).

7.6 Grouping—All displays necessary to support an opera-
tor activity or sequence of activities shall be grouped together.

7.7 Function and Sequence—Displays shall be arranged in
relation to one another according to their sequence of use or the
7.8 Frequency of Use—Displays used most frequently shall be grouped together and placed in the primary visual zone in accordance with Fig. 7 and Fig. 8.

7.9 Importance—Important or critical displays shall be located in the primary visual zone or otherwise highlighted.

7.10 Consistency—The arrangement of displays within a system shall be consistent from application to application.

7.11 Maximum Viewing Distance—The viewing distance from the eye reference point of the seated operator to displays located close to their associated controls shall not exceed 635
mm (25 in.). Otherwise, there is no maximum limit other than that imposed by legibility limitations, which shall be compensated for by proper design.

7.12 Minimum Viewing Distance—The viewing distance from the operator’s eye to the face of the displays, with the exception of cathode ray tube displays and collimated displays, shall never be less than 330 mm (13 in.) and preferably not less than 510 mm (20 in.).

8. Coding of Visual Displays

8.1 Objectives—Coding techniques shall be used to facilitate discrimination between individual displays, identification of functionally related displays, indication of relationship between displays, and identification of critical information within a display.

8.2 Techniques—Displays shall be coded by color, size, location, shape, or flash coding, as applicable.

8.3 Standardization—All coding within the system shall be uniform and shall be established by agreement with the procuring activity.

9. Transilluminated Displays

9.1 Three general types of transilluminated displays that may be used include the following: single- and multiple-legend lights, which present information in the form of meaningful words, numbers, symbols, and abbreviations; simple indicator lights; and, transilluminated panel assemblies, which present qualitative status or system readiness information.

9.2 Use—Transilluminated indicators shall be used to display qualitative information to the operator requiring either an immediate reaction by the operator or to draw attention to an important system status. Such indicators may also be used occasionally for maintenance and adjustment function.

9.3 Equipment Response—Lights, including those used in illuminated push buttons, shall display equipment response and not control position (that is, a lighted ON push button for a pump means that the pump is running, not that the control has been pushed).

9.4 Information—Lights and related indicators shall be used sparingly and shall display only that information necessary for effective system operation.

9.5 Positive Feedback—Changes in display status shall signify changes in functional status rather than simply indicate that a control has been activated (for example, a lighted VALVE CLOSED indicator shall signify that the valve is actually closed, not that the VALVE CLOSED control has been activated). The absence or extinguishment of a signal or visual indication shall not be exclusively used to denote a malfunction, no go, or out-of-tolerance condition; however, the absence of a power on signal or visual indication shall be acceptable to indicate a power-off condition for operational displays only—not for maintenance displays. The absence or extinguishment of a signal or visual indication shall not be used to indicate a ready or in tolerance condition, unless the status or caution light filament and its associated circuitry can be easily tested by the operator and operator perception of such events is not time critical.

9.6 Grouping—Master caution, master warning, master advisory, and summation lights used to indicate the condition of an entire subsystem shall be discriminable from the lights which show the status of the subsystem components, except as required under 9.9.

9.7 Location—When a transilluminated indicator is associated with control, the indicator light shall be so located that it can be associated with the control without error and shall be visible to the operator during control operation. When a transilluminated indicator is used in conjunction with a meter or readout as an indication of an out-of-tolerance condition (such as, a LOW PRESSURE lighted annunciator associated with a pressure meter), it shall be placed directly above the meter. Other arrangements are permissible with the approval of the procuring activity.

9.8 Location, Critical Functions—For critical functions, indicators shall be located within 265 mrad (15°) of the operator’s normal line of sight (as shown in Fig. 8). Warning lights shall be an integral part of, or located adjacent to, the lever, switch, or other control device by which the operator is to take action, or placed as defined in 9.7.

9.9 Maintenance Displays—Indicator lights used solely for maintenance and adjustment shall be covered or nonvisible during normal equipment operation, but shall be readily accessible when required.

9.10 Luminance—The luminance of transilluminated displays shall be compatible with the expected ambient luminance level, and shall be at least 10% greater than the surrounding luminance. Where glare must be reduced, the luminance of transilluminated displays shall not exceed 300% of the surrounding luminance.

9.11 Luminance Control—When displays will be used under varied ambient illuminance, a dimming control shall be provided. The range of the control shall permit the displays to be legible under all expected ambient illuminance. The control shall be capable of providing multiple-step or continuously variable illumination. Dimming to full OFF may be provided in noncritical operations, but shall not be used if inadvertent
failure to turn on an indicator could lead to critical operator failures, such as failure to detect or to perform a critical step in an operation.

9.12 False Indication or Obscuration—Provision shall be made to prevent direct or reflected light from making indicators appear illuminated when they are not, or to appear extinguished when they are illuminated. Self-reflection shall be minimized by proper orientation of the display with respect to the observer.

9.13 Contrast Within the Indicator—The luminance contrast (see 3.1.43) within the indicator shall be at least 50 %. This 50 % luminance contrast requirement does not apply to special displays specifically designed for legibility in sunlight or where legibility is obtained through color contrast (and other techniques) rather than luminance contrast. For low ambient illumination applications, this ratio shall be at least 90 %, with the background luminance less than the figure luminance.

9.14 Lamp Redundancy—Meters, counters, and other displays that use incandescent bulbs to illuminate the display face may incorporate filament redundancy or dual bulbs. When one filament or bulb fails, the intensity of the light shall decrease sufficiently to indicate the need for lamp replacement, but not so much as to degrade operator performance. Lighted annunciators need not have this capability provided a lamp test button is provided.

9.15 Lamp Testing—When indicator lights using incandescent bulbs are installed on a control panel or console, a master light test control shall be incorporated. Panels containing three or fewer lights may be designed for individual press-to-test bulb testing. Circuity shall be designed to test the operation of the total indicator circuit. If dark adaptation is a factor, a means for reducing total indicator light brightness during test operation shall be provided.

9.16 Lamp Removal, Method—Where possible, lamps shall be removable and replaceable from the front of the display panel. The procedure for lamp removal and replacement shall not require the use of tools and shall be easily and rapidly accomplished. If a tool is required, special stowage for it will be provided on the panel.

9.17 Lamp Removal, Safety—Display circuit design shall permit lamp removal and replacement while power is applied without causing failure of indicator circuit components or imposing personnel safety hazards.

9.18 Indicator Covers—If design of legend screen or indicator covers does not prevent inadvertent interchange, a means shall be provided for checking the covers after installation to ensure that they are properly installed.

9.19 Color Coding—Transilluminated displays shall conform to the following color coding scheme.

9.19.1 Flashing Red—Flashing red shall be used to denote emergency conditions that require immediate operator action to avert impending personnel injury, equipment damage, or both. Flash rates shall be in accordance with 9.20. Flashing red lights not installed on consoles shall be limited to general alarm signals only in accordance with U.S. Coast Guard Reg. 113.25-9.

9.19.2 Yellow—Yellow shall be used to advise an operator that a condition exists that is marginal or beyond operational limits, but does not require immediate operator action. Yellow shall also be used to alert the operator to situations in which caution, recheck, or unexpected delay is necessary.

9.19.3 Green—Green shall be used to indicate that the monitored equipment is operating satisfactorily or that a condition is satisfactory and it is all right to proceed.

9.19.4 White—White shall be used to indicate system conditions that do not have right or wrong implications, such as alternative functions (for example, Missile No. 1 selected for launch, and so forth) or transitory conditions (for example, action or test in progress, function available), provided such indication does not imply success or failure of operations.

9.19.5 Blue—Blue may be used for an advisory light, but use of blue shall be avoided whenever possible.

9.19.6 Ship specifications shall not mandate the use of any transilluminated display (such as LEDs) that cannot meet the color codes described.

9.20 Flashing Lights—The use of flashing lights shall be minimized. Flashing lights shall be used only when it is necessary to notify the operator of some condition that is out of tolerance and requires attention. The flash rate shall be within three to five flashes per second with approximately equal amounts of ON and OFF time. Flashing lights shall become steady beaming once the operator acknowledges the flashing light by activating a control that deactivates the flasher circuit. Flashing lights that could be simultaneously active shall have synchronized flashes. If the indicator is energized and the flasher device fails, the light shall illuminate and burn steadily (see 15.2) or a separate indicator showing flashing circuit failure, shall be provided.

9.20.1 Red—Shall be used to alert an operator that the system or any portion of the system is inoperative or that a successful mission is not possible until appropriate corrective or override action is taken. Examples of indicators that shall be coded red are those which display such information as “no-go,” “error,” “failure,” “malfunction,” and so forth.

9.21 Legend Lights—Legend lights (also called annunciators) shall be used in preference to simple indicator lights except where design considerations demand that simple indicators be used. The number of legend lights shall be kept to a minimum. Legend lights shall be used to provide qualitative information, not to give commands.

9.21.1 Color Coding—Legend lights shall be color coded in conformance with 9.19.

9.21.2 Positive Versus Negative Legend—When the operator’s dark adaptation must be maintained, or where legibility in high ambient illumination is critical, the illuminated label/opaque background format shall be used and the illuminated background/opaque label format shall be used only for critical alerting indicators (for example, master warning lights). Where operator dark adaptation is not required, the illuminated background/opaque label format shall be used. Contrast reversal may be used under these conditions to designate displays that have physical appearance similar to legend switches on the same panel.

9.21.3 Lettering—The size and other characteristics of lettering shall conform to Section 27 herein or as otherwise specified by the procuring activity.
9.21.4 Visibility and Legibility—With the exception of danger and caution indicators, the lettering on single-legend indicators shall be visible and legible whether or not the indicator is energized.

9.21.5 Multifunction Legends—Indicators designed to provide alternately presented legends shall present only one legend at a time, that is, only the legend in use shall be visible. If the indicator device uses stacked legends, it shall be designed so that:

9.21.5.1 When the rear legend is energized, it shall not be obscured by the front legend.

9.21.5.2 Parallax is minimized.

9.21.5.3 Rear legends have approximately equal brightness to front legends, and the contrast between rear legends and background is equal to that of the front legend and its background.

9.22 Simple Indicator Lights—Simple indicator lights shall be used only when design considerations preclude the use of legend lights.

9.22.1 Spacing—The spacing between adjacent edges of simple round indicator light fixtures shall be sufficient to permit unambiguous labeling, signal interpretation, and convenient bulb removal.

9.22.2 Coding—Simple indicator lights shall be coded in conformance with Table 2.

9.23 Transilluminated Panel Assemblies—Transilluminated (integrally lighted) panel assemblies may be used to perform the following:

9.23.1 Provide illuminated labels for a control panel.

9.23.2 Provide a light source for illuminating transilluminated control knobs.

9.23.3 Provide illuminated association markings on a control panel, such as connecting lines between controls, outlines around a functionally related group of controls or displays, or both.

9.23.4 Create a pictorialized representation of a system process, communication network, or other information/component organization.

### TABLE 2 Coding of Simple Indicator Lights

<table>
<thead>
<tr>
<th>Size/Type</th>
<th>Red</th>
<th>Yellow</th>
<th>Green</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-mm (0.5-in.)</td>
<td>Malfunction; action</td>
<td>Delay; check; recheck; ahead; or</td>
<td>Go; in tolerance; or</td>
<td>Functional position; action; ready.</td>
</tr>
<tr>
<td>DIAMETER or SMALLER/STEADY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-mm (1-in.)</td>
<td>Master summation (system or subsystem)</td>
<td>Extreme caution (impending danger); or</td>
<td>Master summation (system or subsystem).</td>
<td></td>
</tr>
<tr>
<td>DIAMETER or LARGER/STEADY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-mm (1-in.)</td>
<td>Emergency condition (personnel or equipment disaster);</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIAMETER or LARGER/FLASHING (3 to 5/s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.24 Large, Single Pictorial Graphic Panels—Large, single pictorial graphic panels, used to display system processing, communications networks, or similar applications, shall comply with requirements for visibility, legibility, color, and illumination as specified herein.

9.25 Relamping—When replaceable incandescent lamps are used as the illuminant source for integral lighting of panel assemblies, lamps shall be accessible without disconnecting the panel(s). A sufficient number of lamps shall be provided so that failure of one lamp will not cause any part of the display to be unreadable.

9.26 Brightness—Brightness of illuminated markings and transilluminated controls shall be compatible with the ambient environment and operating conditions (for example, dark adaptation requirements). Brightness control (dimming) by the operator shall be provided where applicable to control/maintain appropriate visibility and operator dark adaptation level.

### 10. Scale Indicators

10.1 Types of Scale Indicators—The types of scale indicators that may be used include the following:

10.1.1 Moving pointer, fixed scale, circular, curved (arc), horizontal straight, and vertical straight.

10.1.2 Fixed pointer, moving scale, circular, curved (arc), horizontal straight, and vertical straight.

10.2 Use—The use of scale indicators shall conform to the criteria in Table 3 as well as the specific criteria contained in this section. Moving-pointer, fixed-scale indicators are preferred to fixed-pointer, moving-scale indicators. The latter should be used only when necessitated by operational requirements or other conditions, and when approved by the procuring activity.

10.3 Type of Information—Scale indicators shall be used to display quantitative information in combination with qualitative information (such as trend and direction of motion) and where only quantitative information is to be displayed and there is no requirement (such as speed and accuracy of response) which demands the use of printers or counters.

10.4 Linear Scales—Linear scales shall be used except where system requirements and the scale clearly dictate non-linearity to satisfy operator information requirements. Nonlinear scales shall be used only with the approval of the procuring activity.

10.5 Scale Marking and Numbering:

10.5.1 Graduation Markings—Scale graduations shall be in increments of one, two, or five units or decimal multiples thereof (except as noted in 10.5.2). No more than three sizes of marks shall be used on any scale. The scales that require three sizes of marks include those which have numbered values in multiples of ten but are graduated in 5 and 10° intervals.

10.5.1.1 Intermediate Marks—The number of intermediate marks between numbered scale pointers shall not exceed nine as shown in Fig. 9 and illustrations of scales graduated in various ways are provided in Fig. 10.

10.5.1.2 Major Marks—Except for measurements that are normally expressed in decimals, whose numbers shall be used for major graduation marks.

10.5.2 Scale Numerals—Intermediate marks shall ordinarily not be numbered. On fixed scales, numerals shall be
vertically oriented, and on rotating scales, numerals shall be radially oriented and positioned so as to be upright when read against the pointer. Bearing dials shall have numerals (and major graduation marks) at either 10 or 30° as shown in Fig. 11.

10.5.3 Scale Length—Scales shall start and end on a major graduation mark even if this puts either or both ends beyond the usable range of the scale (for example, if the maximum voltage which can be read on an instrument is 23 V, the scale shall go at least to 25 V where there could be a major graduation mark). The tips shall never be more than 1.5 mm (⅛ in.) from the scale graduations. The tip shall be equal in width to the minor scale graduations.

10.7.2 Normal Pointer Position—The normal (or zero) pointer position of a scalar indicator shall be at 12 o’clock for right-left directional information, and at 9 o’clock for up-down directional information. For purely quantitative information, either position may be used.

10.7.3 Pivot Point—Pointers shall be pivoted at the right for vertical scales and at the bottom for horizontal scales.

10.7.4 Mounting—The pointer shall be mounted as close as possible to the face of the dial to minimize parallax.

10.7.5 Luminance Contrast—Luminance contrast of at least 75 % shall be provided between the scale face, the markings, and the pointer.

10.7.6 Color—Pointers shall be the same color as the numbers and scale divisions.

10.7.7 Pointers per Shaft—There shall not be more than two pointers on a single shaft.

10.7.8 Reciprocal Pointers—With reciprocal (double-ended) pointers, it shall be easy to distinguish the end that indicates the reading.
10.7.9 Edgewise Indicators—In edgewise indicators such as rectangular meters with straight scales, only the tip of the pointer may be visible. If so, it shall be distinctive and obvious: a flag, spade, or target pointer.

10.7.10 Dial Faces—If the display is used for making a setting, such as tuning in a desired wavelength, it is usually advisable to cover the unused portion of the dial face. The open window shall be large enough to show at least one numbered graduation on each side of any setting. If the display is used in tracking, for example, a heading indicator, the whole dial face shall be exposed.

10.7.11 Coding—When certain operating conditions (such as normal operating temperature or dangerous pressure level) always fall within a limited range of the total scale, these ranges shall be made readily identifiable by means of pattern, color, or shape coding applied to the face of the instrument. Use of red color coding shall be limited to critical situations. Operating zones may be shape coded when the indicator must be viewed in very low-light-level work environments, for example, 0.07 to 0.7 cd/m² (0.02 to 0.2 ft·L), or where the illuminant color will cause difficulty in discrimination of colors. See Fig. 12.

10.7.11.1 Use—Coding on the face of scale indicators may be used to convey such information as desirable operating range, dangerous operating level, caution, undesirable, and inefficient.

10.7.11.2 Pattern or Color Coding—When certain operating conditions always fall within a given range on the scale,
these areas shall be made readily identifiable by means of pattern or color coding applied to the face of the instrument. Color or pattern coding shall be applied to the face of the instrument, not outside the face on the panel or bezel around the instrument. No lines, labels, or any other marks shall be between the instrument pointer and the color or pattern coding.

10.7.11.3 Choice of Colors—Red, yellow, and green may be applied, provided they conform to the meanings specified in 9.19 and are distinguishable under all expected lighting conditions.

10.7.11.4 Pattern Coding—Zone scales may be shape coded when the indicator must be viewed in blackout stations or where the illuminant color will cause difficulty in color band discrimination.

10.8 Moving-Pointer, Fixed-Scale Indicators:

10.8.1 Numerical Progression—Numbered scales shown increase clockwise, from left to right, or from bottom to top, depending on scale layout (circumferential or linear in horizontal or vertical axis).

10.8.2 Orientation of Numerals—Numbers on fixed scales shall appear vertical (upright) to the observer.

10.9 Circular Scales:

10.9.1 Scale Reading and Pointer Movement—To display values ranging from negative through zero to positive, consistently locate the zero point at the 9 or 12 o’clock position. Positive values shall increase when the pointer moves clockwise (to the right), and negative values shall increase when the pointer moves counterclockwise (to the left).

10.9.2 Zero Position and Pointer Movement—When positive and negative values are displayed around a zero point, the magnitude of positive values shall increase with movement of the pointer up or to the right, and the magnitude of negative values shall increase with movement of the pointer down or to
10.9.3 Scale Break—There shall be an obvious break of at least 10° of arc between the two ends of the scale, except on multirevolution instruments such as clocks.

10.9.4 Number of Pointers—Except for clocks or watches (which often have three hands), not more than two coaxial pointers shall be used on a single-dial indicator without approval from the procuring activity.

10.9.5 Aligned Pointers for Check Reading—When a stable value exists for given operating conditions in a group of circular-scale indicators, they shall be arranged either in rows so that all pointers line up horizontally on the 9 o’clock position under normal operating conditions or in columns so that all pointers line up vertically in the 12 o’clock position under normal operating conditions in accordance with Fig. 14. If a matrix of indicators is needed, preference shall be given to the 9 o’clock position.

10.9.6 Relative Position of Scale Marks and Numbers—When reading time and accuracy are critical, circular scale markings and location of associated numbers shall be arranged to prevent pointers from covering any portion of scale marks or numerals, and scale marks/numbers shall be on, or close to, the plane of the pointer tip (that is, to avoid visual parallax) in accordance with Fig. 15. If readout accuracy is not critical (the gross relationship between the pointer and the numeral is all that is required), then arrangement of numerals inside the scale annulus is acceptable. (See examples in Fig. 16.)

10.10 Curved (Arc), Horizontal, or Vertical Straight Scales:

10.10.1 Scale Reading and Pointer Movement—The magnitude of the scale reading shall increase with movement of the pointer up or to the right.

10.10.2 Zero Position and Pointer Movement—The position of the zero value on curved or straight scales shall conform to criteria in Fig. 13.

10.10.3 Relative Position of Pointers, Scales, and Numerals—The numbers shall be located on the side of the graduation marks opposite the pointer. The graduation marks shall be aligned on the side of the pointer and stepped on the side of the numbers. The relative position of pointers, scales, and numerals shall conform to criteria in Fig. 16.

10.11 Fixed-Pointer, Moving-Scale Indicators:

10.11.1 Open Window Display—When the display will be used primarily for setting in a value (for example, tuning to a desired wavelength), only the portion of the scale of interest shall be exposed, that is, the rest of the scale is covered to reduce visual clutter and confusion. The open window shall be of sufficient size to permit view of at least one numbered graduation either side of the desired setting, that is, at least two number values shall appear within the window at all times unless the scale is finite and the dial cannot be rotated continuously through successive rotations in the same direction. If the display will be used for tracking (as in the case of a directional indicator), the entire face of the dial shall be exposed.

10.11.2 Circular Scales—There are ambiguities in associating moving circular scales with control movements; thus moving-scale fixed-pointer indicators are not recommended. Moving circular scales necessarily violates one of these principles of human engineering:
When a dial scale is of finite length, it should be numbered so that value increase is clockwise. The zero starting point should be approximately at the 7 o'clock position. There should be an obvious "break" between the two ends of the scale of at least 10° of arc.

When multirevolution pointer movement is involved, the zero reference should be at the top of the dial, and there should be no break between scale ends. No more than two pointers shall be used except for special cases, e.g., clock (with second hand).

Azimuth dial scales shall be laid out with the zero (or north) reference at the top of the dial, and scale values shall increase clockwise at least every 30° reference should be numbered.

Positive/negative dial formats shall be laid out with the zero (or "null" position) located at the 9-, 12-, or 3-o'clock position. Scale values shall increase right or left, or up or down as appropriate to provide positive/negative pointer movement relationships.

FIG. 13 Zero Position and Pointer Movement for Circular Dial Displays
10.11.2.1 Principle 1—Scale numbers shall increase in a clockwise direction. Values on moving circular scales shall therefore increase with counterclockwise rotation of the dial face.

10.11.2.2 Principle 2—The direction of movement of the associated control shall be compatible with the direction of movement of the dial, for example, clockwise movement of the control shall result in clockwise movement of the dial.

10.11.2.3 Principle 3—Clockwise movement of a control shall result in an increase.

10.11.2.4 If Principle 2 is compromised, for example, clockwise movement of the control results in counterclockwise movement of the dial, operators err in the initial direction of turn. If Principle 3 is compromised, a standard control movement-system relationship is violated.

10.11.3 The following practices are recommended for designing circular moving scales to minimize the effects of incompatibilities:

10.11.3.1 The numbers shall increase clockwise around the face for controls without dial face masks. Therefore, the dial face moves counterclockwise to increase readings.

10.11.3.2 If the associated control has no direct effect on the performance of the equipment (such as tuning in radio stations, and so forth), the scale shall rotate counterclockwise (increase) when the associated knob or crank is turned counterclockwise.

10.11.3.3 If the associated control has a direct effect on the performance of the equipment (such as speed, direction, and so forth), the scale shall rotate counterclockwise (increase) with a clockwise, upward, or rightward movement of the associated control.

10.11.4 Straight Scales Moving Vertically and Horizontally—Straight scales that move vertically and horizontally exhibit the same direction-of-motion ambiguities as circular-moving scales. The numbers shall be printed so they increase from bottom to top or from left to right on the scale plate itself. Then the scale shall increase (move downward or
to the left) when the associated knob or crank is moved clockwise or when the associated lever is moved upward or to the right.

10.11.5 Accepted Deviations—Deviations from the previously listed scale-design principles may be made when other considerations have prime importance. Certain unique applications of scales require other design features and compromises may be required. For example, an azimuth indicator with the numerical progression of 30, 60, 90, and so forth, is less satisfactory than those previously recommended. However, this arrangement represents a compromise between the best numbering progression and a manageable size of the dial. Where the azimuth indicator is a small dial, the numbered cardinal points, north, east, south, west, serve as anchoring points in interpreting this indication, and a progression by 30’s is a good solution. Where the dial can be made large enough, the major intervals shall be marked by 10’s.

10.12 Nonlinear Scales—Nonlinear scales condense a large range into a relatively small space, yet permit sensitive readings at certain critical ranges of the scale. When error tolerances are a constant percentage of the indication, a logarithmic scale is very suitable. However, logarithmic scales shall show enough numbered graduation marks to prevent operators from reading the scale as if it were linear.

10.13 Moving Tape Displays—When the scale length required for acceptable readout accuracy exceeds the limits of the capacity of the display package, that is, compaction of scale markings would make the display legible or subject to readout error, moving-tape scale format shall be considered.

10.14 Composite Scalar/Pictorial Displays—Combination of scales, pointer, or pictorialized symbols may be used to combine functionally related information into a single instrument or display (for example, artificial horizon/command heading, true/relative bearing, and other similar combinations). Design of significant reference features (or ship symbols, or pitch scales, and so forth) shall conform to the general criteria herein relative to direction-of-motion, scale-pointer relationships, legibility, and so forth. Color contrast shall be used to aid the operator in differentiating between various elements of the combined or composite display (such as dark land versus light sky, and so forth).

10.15 Head-Up Display—The head-up display (a positional/command type of display) typically projected on the windshield or window in front of an operator to provide information without the operator having to look at instrument panel or the console displays) may be considered only with the express approval of the procuring agency.
11. Cathode Ray Tube (CRT) Displays

11.1 Signal Size—When a target of complex shape is to be distinguished from a nontarget shape that is also complex, the target signal shall subtend not less than 6 mrad (20 min) of visual angle and shall subtend not less than ten lines or resolution elements. Image quality shall be consistent with the operator’s needs.

11.2 Viewing Distance—A 400-mm (16-in.) viewing distance shall be provided whenever practicable. When periods of scope observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 250 mm (10 in.). Design shall permit the observer to view the scope from as close as desired. Displays that must be placed at viewing distances greater than 400 mm (16 in.) as a result of other considerations shall be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing, and resolution.

11.3 Screen Luminance—The ambient illuminance shall not contribute more than 25% of screen brightness through diffuse reflection and phosphor excitation. A control shall be provided to vary the CRT luminance from 10% of minimum ambient luminance to full CRT luminance. A control shall be provided to vary the luminous symbol/dark background or dark symbol/luminous background contrast ratio. CRTs shall comply with 13.11.

11.4 Faint Signals—When the detection of faint signals is required and when the ambient illuminance may be above 0.25 fc (2.7 lx), scopes shall be hooded, shielded, or recessed. (In some instances, a suitable filter system may be used, subject to approval by the procuring activity.)

11.5 Luminance Range of Adjacent Surfaces—The luminance range of surfaces immediately adjacent to scopes shall be between 10 and 100% of screen background luminance. With the exception of emergency indicators, no light source in the immediate surrounding area shall be of a greater luminance than the CRT signal.

11.6 Ambient Illuminance—The ambient illuminance in the CRT area shall be appropriate for other visual functions (setting controls, reading instruments, maintenance) but shall not degrade the visibility of signals on the CRT display. When a CRT display is used in variable ambient illuminance, illuminance controls shall be provided to dim all light sources, including illuminated panels, indicators, and switches in the immediate area. Automatic adjustment of CRT brightness may be used if the CRT brightness is automatically adjusted as a
function of ambient illuminance, and the range of automatic adjustment is adequate for the full range of ambient illuminance.

11.7 Reflected Glare—Reflected glare shall be minimized by proper placement of the scope relative to the light source, use of a hood or shield, or optical coatings or filter control over the light source.

11.8 Adjacent Surfaces—Surfaces adjacent to the scope shall have a dull matte finish. 

11.9 Pictorial/Graphic Situation Formats—Pictorial or situation data such as plan position indicator data, shall be presented as luminous symbols/dark background.

11.10 Font Legibility—Where alphanumeric characters appear on CRT-like displays, the font style shall allow discrimination of similar characters, such as Letter 1 and Number 1; Letter Z and Number 2.

12. Large-Screen Displays

12.1 Use—Large-scale displays may be used when:

12.1.1 A group of operators frequently refer to the same information and are required to interact as a team based on the same information.

12.1.2 One or more members of a team of operators must move about, yet require frequent referral to information required to make decisions, and which they cannot carry with them, or do not have displayed at their assigned position(s).

12.1.3 Space or other constraints preclude the use of individual displays for each team member to call up commonly used information.

12.1.4 It may be desirable to have general information available to persons who shall not interrupt ongoing group operations by looking over the shoulder(s) of individual operator(s) to see their individual displays.

12.2 Avoidance—Large-screen displays shall not be used when the environmental conditions do not allow satisfactory observational geometry to ensure that all critical operators have appropriate visual access in terms of viewing distance, angle, and lack of interference from intervening objects, personnel, or ambient lighting. If the display is optically projected, see 13.8.

12.3 Viewing Distance—The display shall not be placed further from an observer than will provide appropriate resolution of critical detail presented on the display (see legibility requirements of Section 27). The display shall not be closer to any observer than one half the display width or height, whichever is greater.

12.4 Physical Interruption of View—Large-screen displays shall not be located with respect to critical observers so that the view of the display is obscured regularly by persons moving about by normal traffic patterns.

12.5 Control of Displayed Information—Large-screen group display systems shall be designed so that critical information cannot be modified or deleted inadvertently or arbitrarily, and therefore:

12.5.1 Control of changes in the group display shall be under the control of designed operators who operate according to preestablished procedures, upon command of a person in charge, or both.

12.5.2 When an individual must make changes that are of interest only to him or her, a separate, remote display shall be provided.

12.6 Content of Displayed Information—The content of displayed information shall be evident to a trained observer without requiring reference to display control settings.

12.7 Mounting Height—Large-screen displays, such as status boards in CIC rooms, which are mounted vertically, shall be no lower than 457.2 mm (18 in.) (preferred), 304.8 mm (12 in.) absolute, above the deck, or no higher than 1981.2 mm (78 in.) above the deck.

13. Other Displays

13.1 Types—Where applicable, direct-reading counters, printers, plotters, flags, optical projection, LED, gas discharge, liquid crystal, and electroluminescent displays may be used providing the color codes of 9.19 are not violated.

13.2 Applications—The selection of the above types of displays for various applications shall be based on the following specific criteria as well as the criteria in Table 2. Plotters, printers, and recorders shall not be used as the primary display for systems.

13.3 Counters:

13.3.1 Use—Counters shall be used for presenting quantitative data when a continuous trend indication is not required and when a quick, precise indication is required.

13.3.2 Mounting—Counters shall be mounted as close as possible to the panel surface so as to minimize parallax and shadows and maximize the viewing angle. When counters are used in equipment that is mounted on a vertical surface, the mounting height shall provide for full view of the counter wheel.

13.3.3 Spacing Between Numerals—The horizontal separation between numerals shall be between one quarter and one half the numeral width. Commas shall not be used.

13.3.4 Movement:

13.3.4.1 Snap Action—Numbers shall change by snap action in preference to continuous movement.

13.3.4.2 Rate—Numbers shall follow each other not faster than two per second when the observer is expected to read the numbers consecutively.

13.3.4.3 Direction—The rotation of the counter reset knob shall be clockwise to increase the counter indication or to reset the counter.

13.3.4.4 Reset—Counters used to indicate the sequencing of equipment shall be designed to be reset automatically upon completion of the sequence. Provision shall also be made for manual resetting. Where push buttons are used to reset mechanical counters manually, actuating force required shall not exceed 16.7 N (60 oz).

13.3.5 Display Design—Numerical design, movement (rate and direction), and arrangement shall be as shown in Fig. 17 and Table 4.

13.3.6 Illumination—Counters shall be self-illuminated when used in areas in which ambient illumination will provide display luminance below 3.5 cd/m (1 ft-L).

13.3.7 Finish—The surface of the counter drums and surrounding areas shall have a dull finish to minimize glare.
13.3.8 Contrast—Color of the numerals and background shall provide high contrast (black on white or converse, as appropriate).

13.4 Printers:

13.4.1 Use—Printers shall be used when a visual record of data is necessary or desirable. Use of printers shall conform to Table 3.
13.4.2 Visibility—The printed matter shall not be hidden, masked, or obscured in a manner that impairs direct reading.

13.4.3 Contrast—A minimum of 75% luminance contrast shall be provided between the printed material and the background on which it is printed.

13.4.4 Illumination—The printer shall be provided with internal illumination if the printed matter is not legible in the planned operational ambient illumination.

13.4.5 Take-up Provision—A take-up device for printed material shall be provided.

13.4.6 Annotation—Where applicable, printers shall be mounted so that the printed matter (for example, paper, metallized paper) may be easily annotated while still in the printer.

13.4.7 Legibility—The print output shall be free from character line misregistration, character tilt, or smear.

13.4.8 Printed Tapes—The information on the tapes shall be printed in such a manner that it can be read as it is received from the machine without requiring the cutting and pasting of tape sections.

13.4.9 Control, Replenishment, and Service—Printers shall conform to the criteria of 13.5.8 for plotters and recorders.

13.5 Plotters and Recorders:

13.5.1 Use—Plotters and recorders may be used when a visual record of continuous graphic data is necessary or desirable.

13.5.2 Visibility—Critical graphics (those points, curves, and grids that must be observed when the recording is being made) shall not be obscured by pen assembly, arm, or other hardware elements.

13.5.3 Contrast—A minimum of 50% luminance contrast (see 3.1.43) shall be provided between the plotted function and the background on which it is drawn.

13.5.4 Take-Up Device—A take-up device for extruded plotting materials shall be provided when necessary or desirable.

13.5.5 Job Aids—Graphic overlays should be provided where they may be critical to proper interpretation of graphic data as it is being generated. Such aids shall not obscure or distort the data.

13.5.6 Smudging/Smearing—The plot shall be resistant to smudging or smearing under operational use.

13.5.7 Annotation—Where applicable, plotters and recorders shall be designed or mounted so that the operator can write on or mark the paper while it is still in the plotter/recorder.

13.5.8 Control, Replenishment, and Service—Plotters and recorders shall conform to criteria herein with regard to the following:

13.5.8.1 Controls and displays used to start, stop, or adjust the machine and critical operating elements.

13.5.8.2 Positive indication of the remaining supply of plotting materials (paper, ink, ribbon).

13.5.8.3 Insertion, adjustment for operation, and removal of paper, replenishment of ink supply, replacement of pen, or other items determined to be operator tasks, without requiring disassembly, special equipment, or tools.

13.5.8.4 Minor servicing on site by a technician, such as the adjustment of the drive system, cleaning, or replacement of operating items that ordinarily would not be available to an operator.

13.6 Flags:

13.6.1 Use—Flags shall be used to display qualitative, nonemergency conditions. Use of flags shall conform to Table 3.

13.6.2 Mounting—Flags shall be mounted as close to the surface of the panel as possible without restricting their movement or obscuring necessary information.

13.6.3 Snap Action—Flags shall operate by snap action.

13.6.4 Contrast—A minimum of 75% luminance contrast (see 3.1.43) shall be provided between flags and their backgrounds under all expected lighting conditions.

13.6.5 Malfunction Indication—When flags are used to indicate the malfunction of a visual display, the malfunction position of the flag shall obscure part of the operator’s view of the malfunctioning display and shall be readily apparent to the operator under all expected levels of illumination.

13.6.6 Legend—When a legend is provided on the flag, the lettering shall appear upright when the flag assumes the active or no-go position.

13.6.7 Test Provision—A convenient means shall be provided for testing the operation of flags.

13.7 Large-Screen Optical Projection Displays:

13.7.1 Use—Providing ambient light can be properly controlled, optical projection displays are suitable for applications requiring group presentation, pictorial and spatial information, past history versus real-time presentation, synthetically generated pictures, simulation of the external world, and superposition of data from more than one source. Rear projection shall be used where physical obstructions to front projection result in poor visibility or where work areas require high ambient illumination for other activities.

13.7.2 Seating Area—Viewing distance/image width relationship and off-centering viewing of optical projection displays for group viewing shall conform to the preferred limits of Table 5 and shall not exceed the acceptable limits indicated. For individual viewing from a fixed location, off-centerline viewing shall not exceed 175 mrad (10°).

13.7.3 Image Luminance and Light Distribution—Image luminance and light distribution shall conform to the preferred limits and shall not exceed the acceptable limits of Table 5.
any case, the luminance of the screen center at maximum viewing angle shall be at least half its maximum luminance.

13.7.4 Legibility of Projected Data:

13.7.4.1 Style—A simple style of numerals and letters shall be used. Capital letters shall be used, rather than lowercase, except for extended copy or lengthy messages. Stroke width shall be ⅛ to ⅜ of numeral or letter height, but may be narrower for light markings on a dark background. Stroke width shall be the same for all letters and numerals of equal height. Letter and numeral widths, character spacing, and word spacing shall conform to 28.10.

13.7.4.2 Size—The height of letters and numerals (except single-stroke characters, such as the Number 1) shall not be less than 4.5 mrad (15 min) of visual angle and, in no instance, shall be less than 3 mrad (10 min) as measured from the longest anticipated viewing distance.

13.7.5 Contrast:

13.7.5.1 Luminance Ratio—Under optimal ambient lighting conditions, the luminance ratio (see 3.1.44) for optically projected displays shall be 500:1. The minimum luminance ratio for viewing charts, printed text, and other line work via slides or opaque projectors shall be 5:1. For projections that are limited in shadows and detail, such as animation and photographs with limited luminance range, the minimum luminance ratio shall be 25:1. For images that show a full range of colors in black-and-white photographs), the minimum luminance ratio shall be 100:1.

13.7.5.2 Direction of Contrast—Contrast may be either light on a dark background or vice versa, except where superposition is used. For subtractive superposition (at the source), data shall be presented as dark markings on a transparent background. For additive superposition (at the screen), data shall be presented as light markings on an opaque background. Colored markings against colored backgrounds of comparable brightness shall be avoided.

13.7.6 Alignment—Misregistration of superimposed alphanumeric data or other symbols shall be minimized.

13.7.7 Keystone Effects—Projector-screen arrangement shall minimize the keystone effect, that is, the distortion of projected data proportions caused by nonperpendicularity between projector and screen.

13.8 Light-Emitting Diodes (LEDs):

13.8.1 General—The standard for LEDs will be the same as the requirements for transilluminated displays, Section 9 of this practice, unless otherwise specified herein.

13.8.2 Use—LEDs may be used for transilluminated displays, including legend and simple indicator lights, and for matrix (alphanumeric) displays, only if the display is bright enough to be readable in the environment of intended use enclosure, bright sunlight, low temperature.

13.8.3 Intensity Control—The dimming of LEDs shall be compatible with the dimming of incandescent lamps.

13.8.4 Color Coding—LED color coding shall conform to 9.19 herein, with the exception that red alphanumeric displays and red bar segments for vertical, horizontal, and circular meters may be used with approval from the procuring activity. However, red LEDs shall not be located in the proximity of emergency red lights used as outlined in 9.19.1.

13.8.5 Lamp Testing—LED indicator lights with 100 000 h or longer MTBF (Mean Time Between Failure) shall not require the lamp test capability specified in 9.15.

13.9 Dot Matrix/Segmented Displays:

13.9.1 General—The design criteria below shall be applied to those displays (LED, CRT, gas discharge, liquid crystal, and incandescent) used for presentation of alphanumeric and symbolic information.

13.9.2 Use—Dot matrix, 14-segment, and 16-segment displays may be used for applications involving interactive computer systems, instruments, navigation, and communication equipment, where the presentation of alphanumeric, vector-graphic, symbolic or real-time information is required. Seven-segment displays shall only be used for applications requiring numeric information.

13.9.3 Symbol Definition—The smallest definition for a dot matrix shall be 5 by 7 dots, with 7 by 9 preferred. If system requirements call for symbol rotation, a minimum of 8 by 11 is required, with 15 by 21 preferred.

13.9.4 Alphanumeric Character and Symbol Sizes—Alphanumeric and symbolic characters shall not subtend less than 4.7 mrad (16 min) of visual angle.

13.9.5 Use of Uppercase—Alphanumeric characters shall be uppercase.

13.9.6 Viewing Angle—The optimum viewing angle is perpendicular to the display. Dot matrix or segmented displays shall not be presented for viewing at an angle larger than 61° off axis.

13.9.7 Emitter Color—Monochromatic displays shall use the following colors in order of preference: green (555 nm), yellow (575 nm), orange (585 nm), and red (660 nm). Blue emitters shall not be used.

13.9.8 Intensity Control—Dimming controls shall be provided where applicable to maintain appropriate legibility and operator dark adaptation level.

13.9.9 Lamp Testing—See 9.15.

13.9.10 Location of Red Alphanumeric LEDs/Segmented Displays—Red LEDs/segmented displays shall not be grouped with or located adjacent to red warning lights.
13.10 Electroluminescent Displays:
13.10.1 Use—Electroluminescent displays may be used wherever system requirements dictate the use of transilluminated displays provided they comply with 9.19. In addition, they may replace existing mechanical instrumentation while offering advantages of lighter weight, conservation of panel space, lower power requirements, lack of heat production, uniform distribution of illumination, longer life, elimination of parallax, and flexibility of display. Electroluminescent displays may also be used where sudden lamp failure could result in catastrophic consequences.

13.10.2 Alphanumeric Character and Symbol Sizes—The height of alphanumeric characters and geometric and pictorial symbols shall not sub tend less than 4.5 mrad (15 min) of visual angle. Alphanumeric characters shall be composed of uppercase letters.

13.11 Special Requirements for TV Display:
13.11.1 Resolution—Resolution shall be 400 lines or greater both horizontally and vertically except that for low-resolution applications, line spacing need not be closer than needed to subtend 1 min of arc from the normal viewing position.

13.11.2 Rate and Interlacing—Except for slow-scan systems for reproduction of static images, the frame rate for sampling of video material shall be a minimum of 30/s. There shall be two display scan fields per frame period (or a minimum of 60/s) with the lines of the second scan in the frame period interlaced with the lines of the first scan.

13.11.3 Phosphors—The phosphors for TV screens shall have short or medium persistence and high output such as the P-4 or P-23 for black-and-white monitors and the P-22 or P-27 for color monitors.

13.11.4 Distortion—Spot diameter shall not vary by more than a ratio of 1.5 to 1.0 at any two points on the screen. Distortion shall not be sufficient to cause obvious nonlinearity anywhere on the screen when viewing alphanumeric formats or picture images.

13.11.5 Gray Scale—There shall be a minimum of at least five distinguishable gray scale levels. When the requirements include interpretation of handwriting, resolution of fine detail, or complex image interpretation, up to eight gray scale levels shall be provided.

13.12 Special Requirements for Radar/Sonar Displays:
13.12.1 Types of Scans—The type of scan selected shall be appropriate to the operator’s task in using the radar/sonar data. Commonly used scan types shall be selected in preference to novel or experimental scan types except as approved by the procuring activity.

13.12.2 Display Scale Sizes and Range Ring Values—Display scale shall be selected on the basis of the following criteria.

13.12.2.1 If rings are to be used, the display scales selected shall be compatible with the use of a constant number of range rings regardless of the scale, as given in Table 6.

13.12.2.2 Display systems capable of presenting alphanumerics shall present range ring values on the CRT.

13.12.3 Appropriate scale limits considering radar/sonar characteristics such as maximum range, range resolution, bearing resolution, and maximum range of detection. For example, the display scales for use with a shipboard surface search radar having a minimum range of 200 m (656.2 ft) and a maximum range of 60 km (57.3 miles) might be as follows:

13.12.3.1 Minimum—2 km (1.24 miles) not more than ten times the minimum range value, to capitalize on range determination at close-in ranges as in station keeping.

13.12.3.2 Maximum—75 km (46.6 miles) accommodates maximum range of the radar and is a good scale for estimation and interpolation.

13.12.4 Area and scaling limits suggested by representative operational situations including warfare operations, search patterns, maneuvers, flight operations, and so forth. For example, an aircraft carrier that may have a number of missions involving close-in aircraft operations at ranges from 15 to 30 km (9.3 to 18.6 miles) shall have a 30-km (18.6-miles) display scale for monitoring and control of aircraft on such missions.

14. Audio Displays, General Information
14.1 Use—Audio displays shall be provided when:

14.1.1 The information to be processed is short, simple, and transitory, requiring immediate or time-based response.

14.1.2 The common mode of visual display is restricted by overburdening; ambient light variability or limitation; operator mobility; degradation of vision by vibration, hypoxia, or other environmental considerations; or anticipated operator inattention.

14.1.3 The criticality of transmission response makes supplementary or redundant transmission desirable.

14.1.4 It is desirable to warn, alert, or cue the operator to subsequent additional response.

14.1.5 Custom or usage has created anticipation of an audio display.

14.1.6 Voice communication is necessary or desirable.

14.1.7 Signal Type—When an audio presentation is required, the optimum type shall be presented in accordance with Table 7.

14.2 False Alarms—The design of audio display devices and circuits shall preclude false alarms.

14.3 Failure—The audio display device and circuit shall be designed to preclude warning signal failure in the event of system or equipment failure and vice versa.

14.4 Circuit Test—All audio displays shall be equipped with circuit test devices or other means of operability test.

14.5 Use with Several Visual Displays—One audio signal may be used in conjunction with several visual displays, provided that immediate discrimination is not critical to personnel safety or system performance.

15. Audio Warnings
15.1 Audible Alarms—Audible alarms shall be provided, as necessary, to warn personnel of impending danger, to alert an
operator to a critical change in system or equipment status, and to remind the operator of a critical action, or actions, that must be taken. An alerting/warning system or signal shall provide the operator with a greater probability of detecting the triggering condition than his normal observation would provide in the absence of the alerting/warning system or signal.

15.2 Audible Alarms and Visual Displays at Consoles and Other Work Stations—Audible alarms shall be used as a supplement to visual alarms at operator consoles and other work stations to notify an operator that a serious malfunction has occurred, the nature of which is discernible through some visual display(s). When a supplemental audible alarm is used at a console or work station, it shall be a siren (used in conjunction with a flashing red light) for a danger situation or a horn (used with a yellow light) for a caution situation. Caution signals shall be readily distinguishable from danger signals and shall be used to indicate conditions requiring awareness, but not necessarily immediate action. The audible alarm shall be silenced when the operator acknowledges the visual alarm display. If a second malfunction occurs in the same equipment or system before the first malfunction has been corrected, both the audible and visual alarms shall operate again. Other types of audible alarms may be used in lieu of the two listed here with the written approval of the procuring agency. Whichever signals are selected, the danger and caution alarms must be readily distinguishable from each other and used consistently throughout the ship. Acceptable alarm types for emergency and primary alarms are shown in Fig. 18.

15.3 General Use Audible Alarms—Audible alarms shall be used throughout the ship to notify crew (and passengers for commercial ships) of hazardous situations such as fire and smoke detection, release of fire-extinguishing material in a closed space, impending collision, and ship exposure to biological, chemical, or radiological agents. In addition, audible alarms may be placed in certain crew accommodation spaces (for example, the engineer’s berthing compartment) to notify them of a malfunction or problem in a part of the ship for which they are responsible. Audible alarms may also be used to notify an operator of an incoming telephone call or a change in the engine room telegraph (EOT) when the possibility exists that the operator would be in an area where such supplemental alarms would be needed. When general audible alarms are used, they shall comply with the following requirements.

15.4 Visual Alarms Used with General Audible Alarms—Visual alarms (that is, rotating or flashing lights) shall be used
in conjunction with general audible alarms in spaces with high ambient noise levels or under other circumstances where the audio alarms may not be discernible. When used the visual alarms shall comply with the following:

15.4.1 Be clearly visible and distinguishable, either directly or by reflection, in all parts of the space in which they are used;
15.4.2 Be of a color in accordance with 9.19, color coding (for Navy ships) or IMO standards for commercial ships;
15.4.3 Flash in accordance with 9.20; and
15.4.4 Flash as long as the audible alarm is activated, and for those audible alarms which are cancelled by activation of an alarm acknowledge switch the visual alarm shall be cancelled by the same alarm acknowledge switch that is used to silence the audible alarm.

16. Characteristics of Audible Alarms

16.1 Frequency:

16.1.1 Range—The range shall be between 200 and 5000 Hz and, if possible, between 500 and 1500 Hz. When signals must travel over 300 m (985 ft), frequencies below 1000 Hz shall be used. Frequencies below 500 Hz shall be used when signals must bend around obstacles or pass through partitions.

16.1.2 Different Characteristics—When several different audible alarms are to be used concurrently, discernible differences in the spectral composition or the temporal pattern, or both, shall be provided. When specific recognition of individual alarms is important (for example, the differences between a general alarm and fire detected alarm), their differences shall be coded (that is, the waveforms altered) to ensure that each alarm is quickly and easily distinguished.

16.1.3 Spurious Signals—The frequency of a warning tone shall be different from that of the electric power used in the system to preclude the possibility that a minor equipment failure may generate a spurious signal.

16.2 Intensity:

16.2.1 Compatibility with Acoustical Environment—The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal areas. See 17.1.

16.2.2 Compatibility with Clothing and Equipment—As applicable, audio signals shall be loud enough to be heard and understood through equipment or garments (for example, parka hood, NBC protective hood, hearing protective devices) covering both ears of the listener.

16.2.3 Discomfort—Audio warning signals shall not be of such intensity as to cause discomfort or “ringing” in the ears as an aftereffect.

17. Signal Characteristics in Relation to Operational Conditions and Objectives

17.1 Audibility—A signal-to-noise ratio of at least 20 dB shall be provided in at least one-octave band between 200 and 5000 Hz at the operating position of the intended receiver. However, in no case shall an audible alarm exceed 120 dB (A) except in extremely noisy compartments in which case the alarm shall exceed the maximum ambient noise level by 10 dB (A) up to a maximum of 140 dB (A).

17.2 Alerting Capability:

17.2.1 Attention—Signals shall not be so startling as to preclude appropriate responses or interfere with other functions by holding attention away from other critical signals.

17.2.2 Onset and Sound Pressure Level—The onset of critical alerting signals shall be sudden, and high sound pressure level shall be provided as specified in 17.1.

17.2.3 Dichotic Presentation—When earphones will be worn in the operational situation, a dichotic presentation shall be used whenever feasible, alternating the signal from one ear to the other by means of a dual-channel headset.

17.2.4 Headsets—Operators who normally wear earphones covering both ears shall have the audible alarms presented in the headset as well as in the work area. A dichotic presentation shall be used so as to provide the audible alarm to one ear and the normal auditory signals to the other on an alternating basis. Binaural headsets shall not be used in an operational environment below 85 dB (A) when that environment may contain sounds that provide the operator with useful information which cannot be presented through the headsets.

17.3 Discriminability:

17.3.1 Use of Different Characteristics—When several different audio signals are to be used to alert an operator to different types of conditions, discriminable difference in intensity, pitch, or use of beats and harmonics shall be provided. If absolute discrimination is required, the number of signals to be identified shall not exceed four.

17.3.2 Coding—Where discrimination of warning signals from each other will be critical to personnel safety or system performance, audio signals shall be appropriately coded. Alarms that are perceptibly different shall correlate with different conditions requiring critically different operator responses (such as maintenance, emergency conditions, and health hazards). Such signals shall be sufficiently different to minimize the operator’s search of visual displays.

17.3.3 Critical Signals—The first 0.5 s of an audio signal requiring fast reaction shall be discriminable from the first 0.5 s of any other signal that may occur. Familiar signals with established names or associations shall be selected. Speech shall be used whenever feasible.

17.3.4 Action Segment—The identifying or action segment of an audio warning signal shall specify the precise emergency or condition requiring action.

17.3.5 Differentiation From Routine Signals—Audio alarms intended to bring the operator’s attention to a warning or a caution condition shall be differentiated from routine signals, such as bells, buzzers, and normal operation noises.

17.3.6 Prohibited Types of Signals—The following types of signals shall not be used as warning devices where possible as a result of confusion that might exist because of the operational environment:

17.3.6.1 Modulated or interrupted tones that resemble navigation signals or coded radio transmissions.
17.3.6.2 Steady signals that resemble hisses, static, or sporadic radio signals.
17.3.6.3 Trains of impulses that resemble electrical interference whether regularly or irregularly spaced in time.
17.3.6.4 Simple warbles that may be confused with the type made by two carriers when one is being shifted in frequency (beat-frequency-oscillator effect).

17.3.6.5 Scrambled speech effects that may be confused with cross-modulation signals from adjacent channels.

17.3.6.6 Signals that resemble random noise, periodic pulses, steady or frequency modulated simple tones, or any other signals generated by standard countermeasure devices (for example, “bagpipes”).

17.3.6.7 Signals similar to random noise generated by air conditioning or any other equipment.

17.4 Compatibility:

17.4.1 Existing Signals—The meaning of audio warning signals selected for a system shall be consistent with warning signal meanings already established for that function.

17.4.2 Acoustic Environment—Established signals shall be used provided they are compatible with the acoustic environment and the requirements specified herein for the voice communication system. Standard signals shall not be used to convey new meanings. See 17.1.

17.5 Masking:

17.5.1 Other Critical Channels—Audio warning signals shall not interfere with any other critical functions or signals or mask any other critical audio signals.

17.5.2 Separate Channels—Where a warning signal delivered to a headset might mask another essential audio signal, separate channels may be provided to direct the warning signal to one ear and the other essential audio signal to the other ear.

18. Verbal Warning Signals

18.1 Nature of Signals—Verbal warning signals shall consist of the following:

18.1.1 An initial alerting signal (nonspeech) to attract attention and to designate the general problem.

18.1.2 A brief standardized speech signal (verbal message) that identifies the specific condition and suggests appropriate action.

18.2 Intensity—Verbal alarms for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver.

18.3 Vocal Criteria:

18.3.1 Type of Voice—The voice used in recording verbal warning signals shall be distinctive.

18.3.2 Delivery Style—Verbal warning signals shall be presented in a formal, impersonal manner.

18.4 Message Content—In selecting words to be used in audio warning signals, priority shall be given to intelligibility, aptness, and conciseness in that order.

18.5 Message Categories:

18.5.1 Critical Warning Signals—Critical warning signals shall be repeated with not more than a 3-s pause between messages until the condition is corrected or overridden by the crew.

18.5.2 Message Priorities—A message priority system shall be established, and more critical messages shall override the presentation of any message occurring below it on the priority list. If two or more incidents or malfunctions occur simultaneously, the message having the higher priority shall be given first. The remaining messages shall follow in order of priority.

In the event of a complete subsystem failure, the system shall integrate previous messages via electronic gating and report the system rather than the component failure.

19. Controls for Audio Warning and Caution Devices

19.1 Automatic or Manual Shutoff—When an audio signal is designed to persist as long as it contributes useful information, a shutoff switch controllable by the operator, the sensing mechanism, or both, shall be provided, depending on the operational situation and personnel safety factors.

19.2 Automatic Reset—Whether audio and caution warning signals are designed to be terminated automatically, by manual control, or both, an automatic reset function shall be provided. The automatic reset function shall be controlled by the sensing mechanism which shall recycle the signal system to a specified condition as a function of time or the state of the signal system.

19.3 Redundant Visual Warning—All nonverbal aural announcements shall be accompanied by a visual announcement which defines the condition. This may be an illuminated display.

19.4 Volume Control:

19.4.1 Automatic or Manual—The volume (loudness) of an audio warning or caution signal shall be designed to be controlled by the operator, the sensing mechanism, or both, depending on the operational situation and personnel safety factors. Control movements shall be restricted to prevent reducing the volume to an inaudible level but in no case shall the volume be less than that of 20 dB.

19.4.2 Ganging to Mode Switches—Volume controls may be ganged to mode switches to provide maximum output during mission phases in which intense noise may occur and to provide reduced volume at other times. Ganging shall not be accomplished if there is a possibility that intense noise may occur in an emergency situation during a mission phase in which the volume would be decreased below an audiable level.

19.4.3 Caution Signal Controls—Audio caution signals shall be provided with manual reset and volume controls.

19.5 Duration—Audio warning and caution signals shall continue until the appropriate operator response is made, alarm acknowledged, or malfunction corrected. Completion of a corrective action by the operator or by other means shall automatically terminate the signal.

19.6 Duration Limitations—In an emergency situation, signals that persist or increase progressively in level shall not be used if manual shutoff may interfere with the corrective action required.

20. Speech Transmission Equipment

20.1 Frequency—Microphones and associated system-input devices shall be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (200 to 6100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6100 Hz, the minimum acceptable frequency range shall be 250 to 4000 Hz.

20.2 Dynamic Range—The dynamic range of a microphone used with a selected amplifier shall be great enough to admit variations in signal input of at least 50 dB.
20.3 **Noise-Cancelling Microphones**—In very loud, low-frequency noise environments (100 dB overall), noise-cancelling microphones shall be used and shall be capable of effecting an improvement of not less than 10-dB peak-speech to root-mean-square-noise ratio as compared with nonnoise-cancelling microphones of equivalent transmission characteristics.

20.4 **Preemphasis**—If necessary, speech system input devices shall use frequency preemphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1500 to and no greater than 9 dB per octave over the frequency range 1500 to 4800 Hz, when no clipping is used.

20.5 **Peak Clipping of Speech Signals**—Where speech signals are to be transmitted over channels showing less than 15 dB, peak-speech to root-mean-square-noise ratios, peak clipping of 12 to 20 dB may be used at system input and may be preceded by frequency preemphasis.

20.6 **Noise Shields**—When the talker is in an intense noise field, the microphone shall be put in a noise shield. Noise shields shall be designed to meet the following requirements:

20.6.1 A volume of at least 250 cm³ (15.25 in.³) to permit a pressure gradient microphone to function normally.

20.6.2 A good seal against the face with the pressure of the hand or the tension of straps.

20.6.3 A hole or combination of holes covering a total area of 65 mm² (0.1 in.²) in the shield to prevent pressure buildup.

20.6.4 Prevention of a standing wave pattern by shape or by use of sound-absorbing material.

20.6.5 No impediment to voice effort, mouth or jaw movement, or breathing.

20.7 **Speech Reception Equipment**:

20.7.1 **Frequency Range**—Headphones and loudspeakers shall be subject to the same frequency response restrictions as microphones and transmission equipment, except that loudspeakers for use in multispeaker installations and multiple channels fed into headphones (for example, where several speech channels are to be monitored simultaneously) shall respond uniformly (+5 dB) over the range 100 to 4800 Hz.

20.7.2 **Loudspeakers for Multichannel Monitoring**:

20.7.2.1 **Monitoring of Speakers**—When several channels are to be monitored simultaneously by means of loudspeakers, the speakers shall be mounted at least 175 mrad (10°) apart in the horizontal plane frontonal quadrant, ranging radially from 788 mrad (45°) left to 788 mrad (45°) right of the operator’s normal forward facing position. Loudspeakers used by a single person (in an area in which there is more than one speaker installed) shall be mounted directly in front of the user and be equipped with a volume control and a jack box for use with headphones.

20.7.2.2 **Filtering**—When additional channel differentiation is required, apparent lateral separation shall be enhanced by applying low-pass filtering (frequency cutoff, \( F_c = 1800 \text{ Hz} \)) to signals fed to loudspeakers on one side of the central operator position. If there are three channels involved, one channel shall be left unfiltered, a high-pass filter with 1000-Hz cutoff shall be provided in the second channel, and a low-pass filter with 2500-Hz cutoff shall be provided in the third channel. A visual signal shall be provided to show which channel is in use.

20.7.3 **Use of Deemphasis**—When transmission equipment uses preemphasis and peak clipping is not used, reception equipment shall use frequency deemphasis of characteristics complementary to those of preemphasis only if it improves intelligibility, that is, deemphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4800 Hz.

20.7.4 **Headsets**—If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities shall be capable of reducing the ambient noise level to less than 85 dB(A). Provisions shall be incorporated to furnish the same protection to those who wear eyeglasses.

20.8 **Operator Comfort and Convenience**:

20.8.1 **Comfort**—Headphones and telephone headsets shall be designed for operator comfort, and no metal parts of the headset shall come in contact with the user’s skin.

20.8.2 **Hands-Free Operation**—Operator microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions.

20.8.3 **Accessibility of Headsets**—Where communication requirements necessitate the use of several telephone headsets, the accessibility of their standby locations shall be determined by operational priority, that is, the most frequently or urgently needed headset shall be the most accessible. Color coding may also be used where operating personnel will have visual contact with headsets under the working conditions.

20.9 **Operating Controls for Voice Communication Equipment**:

20.9.1 **Volume Controls**—Accessible volume or gain controls shall be provided for each communication receiving channel (for example, loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 110 dB overall when using two earphones. The minimum setting of the volume control shall be limited to an audible level, that is, it shall not be possible to disable the system inadvertently with the volume control. While separation of power (on-off) and volume control adjustment functions into a separation of power (on-off) and volume control adjustment functions into separate controls is preferred, shall conditions justify their combination, a noticeable detente position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment. When combined power and volume controls are used, the OFF position shall be labeled.

20.9.2 **Squelch Control**—Where communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. A manually operated, on-off switch to deactivate the squelch when receiving weak signals shall be provided.

20.9.3 **Foot-Operated Controls**—When normal working conditions will permit the operator to remain seated at the working position and access to “talk-listen” or “send-receive” control switches are required for normal operation, or if console operation requires the use of both hands, foot-operated
controls shall be provided. Hand-operated controls for the same functions shall be provided for emergency use and for use when the operator may need to move from one position to another.

20.10 Speaker/Side Tone—The speaker’s verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset.

20.11 Speech Intelligibility:

20.11.1 General—When information concerning the speech intelligibility of a system is required, three recommended methods are available, with the appropriate selection being dependent upon the requirements of the test.

20.11.1.1 The ANSI standard method of measurement of phonetically balanced (PB) monosyllabic word intelligibility, S3.2-1960, shall be used when a high degree of test sensitivity and accuracy is required.

20.11.1.2 The Modified Rhyme Test (MRT) shall be used if the test requirements are not as stringent or if time and training do not permit the use of the ANSI method.

20.11.1.3 The Articulation Index (AI) calculations should be used for estimations, comparison and predictions of system intelligibility based upon ANSI S3.5-1969.

20.11.2 Criteria—The intelligibility criteria shown in Table 8 shall be used for voice communication. The efficiency of communications needed and the type of material to be transmitted shall determine which of the three communication requirements of Table 8 is to be selected.

21. Controls, General Information

21.1 Selection Criteria—Criteria in Table 9 and Table 10 should be used in determining the type of control to be used on control panels or other applications where controls are required.

21.2 Users—The type of control selected and the location of the motion envelope provided for control operation shall ensure that suitably clothed and equipped user personnel with applicable fifth through ninety-fifth percentile body dimensions and fifth percentile strength can operate them.

21.3 Efficiency—Since more operations are right handed than left handed, equipment shall normally be designed for right-handed operation. Other considerations are that hand manipulation is more precise than foot manipulation and that more force can usually be applied by the foot and leg than the hand and arm.

21.4 Distribution of Work Load—Controls shall be selected and distributed so that none of the operator’s limbs will be overburdened.

21.5 G-loading—Where applicable, control selection shall include consideration of operation under variable g-loading on the operator.

21.6 Multirotation Controls—Multirotation controls shall be used when precision is required over a wide range of adjustment.

21.7 Detente Controls—Detente controls shall be selected whenever the operational mode requires control operation in discrete steps.

21.8 Stops—Stops shall be provided at the beginning and end of the range of control positions if the control is not required to be operated beyond the indicated end positions or specified limits.

21.9 Direction of Movement:

21.9.1 Consistency of Movement—Direction of control movement shall be consistent with the related movement of an associated display, equipment component, or vessel (see Table 11 and Fig. 19). With the exception of valve controls, movement of a control forward, clockwise to the right, or up, or pressing a control, shall turn the equipment or component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up.

21.9.2 Multidimensional Operation—When the vessel, the equipment, or the components are capable of motion in more than two dimensions, exception to Section 21.9.1 (Consistency of Movement) may be necessary to ensure consistency or anticipated response (such as forward motion of a directional control causes some vessels to dive, for example, a submarine, or otherwise descend rather than to simply move forward). When several controls are combined in one control device, caution shall be exercised to avoid conflicts (for example, control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

21.9.3 Operator-Control Orientation—Controls shall be oriented with respect to the operator. Where the operator may use two or more vehicle operator stations, the controls shall cause movement oriented to the operator at the effecting station, unless remote visual reference is used.

21.9.4 Valve Controls—Rotary valve controls shall open the valve with a counterclockwise motion and close with a clockwise rotation. Valve controls shall be provided with double-ended arrows labeled OPEN in the counter-clockwise direction and CLOSE in the clockwise direction.

22. Arrangement and Grouping of Controls

22.1 Grouping—All controls that function in sequential operational necessary to a particular task, or that operate together, shall be grouped together along with their associated displays. When several steps of a sequence are selected by one control, the steps shall be arranged by order of occurrence to minimize control movements and event cycling through unnecessary steps. Cycling through the control’s ON/OFF position shall be avoided.

22.2 Sequential Operation—Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate
22.3 Location of Primary Controls—The most important and frequently used controls shall have the most favorable position with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings).

22.4 Consistency—The arrangement of functionally similar or identical controls shall be consistent from panel to panel throughout the system, equipment, or vessel.

22.5 Remote Controls—Where controls are operated at a position remote from the display, equipment, or controlled vessel, they shall be arranged to facilitate direction-of-movement consistency.

22.6 Maintenance and Adjustment—In general, controls used solely for maintenance and adjustment shall be covered during normal equipment operation, but shall be directly accessible and visible to the maintenance technician when required.

22.7 Spacing—Minimum spacing between control shall comply with Table 12 spacing between a control and any adjacent obstruction shall be as shown by the figures referenced by Table 12. Minimum spacing shown shall be increased for operation with gloves, mittens, NBC, or other protective handwear when such operation is a system requirement.
23. Coding of Controls

23.1 Methods and Requirements—The use of a coding mode such as size and color for a particular application shall be governed by the relative advantages and disadvantages of each type of coding. Where coding is used to differentiate among controls, application of the code shall be uniform throughout the system. (See Table 13 for advantages and disadvantages.)

23.2 Location Coding—Controls associated with similar functions shall be in the same relative location from operator work station to work station and from panel to panel.

23.3 Size Coding—No more than three different sizes of controls shall be used in coding controls for discrimination by absolute size. Controls used for performing the same function on different items of equipment shall be the same size. When knob diameter is used as the coding parameter, differences between diameters shall not be less than 13 mm (0.5 in.). When knob thickness is the coding parameter, differences between thicknesses shall not be less than 10 mm (0.4 in.).

23.4 Shape Coding—Primary use of shape coding for controls is for identification of control knobs or handles by “feel;” however, shapes shall be identifiable both visually and tactually. When shape coding is used:

23.4.1 The coded feature shall not interfere with ease of control manipulation.

23.4.2 Shapes shall be identifiable by the hand regardless of the position and orientation of the control knob or handle.

23.4.3 Shapes shall be tactually identifiable when gloves are worn, where applicable.

23.4.4 A sufficient number of identifiable shapes shall be provided to cover the expected number of controls that require tactile identification.

23.4.5 Shape-coded knobs and handles shall be positively and nonreversibly attached to their shafts to preclude incorrect attachment when replacement is required.

23.4.6 Where possible, control shapes shall resemble the equipment, system, or control function that the control operates.

23.4.7 Color Coding:

23.4.7.1 Lighting—Color coding of control surfaces shall not be used when visibility of the controls is restricted or obstructed, or when illumination lighting is below 0.35 cd/m² (0.1 ft-L) or of some color other than white.

23.4.7.2 Related Controls—When related controls and displays are color coded, they shall be coded the same color.

23.4.7.3 Emergency Controls—All emergency controls used under only white lighting shall be colored red. If red lighting is to be used during any portion of a mission, controls which would have been coded red shall be coded by orange-yellow and black striping. To give emergency controls visual emphasis, color coding of other controls shall be kept to a minimum.

23.4.7.4 Choice of Colors—Controls shall be black (17038, 27038, or 37038) or gray (26231 or 36231). If color coding is required, the following colors identified in Table 14 shall be selected for control coding.

23.4.7.5 Relation to Display—When color coding must be used to relate a control to its corresponding display, the same color shall be used for both the control and the display.

23.4.7.6 Control Panel Contrast—The color of the control shall provide contrast between the panel background and the control.

23.4.7.7 Ambient Lighting and Color-Coding Exclusion—Color coding shall be compatible with anticipated ambient lighting throughout the mission. Color coding shall not be used as a primary identification medium if the operator’s adaptation to that light, varies as the result of such factors as solar glare, filtration of light, and variation from natural to artificial light.

23.5 Labeling of Controls—Control labeling shall conform to the criteria in 29.7.

23.6 Compatibility with Handwear—Controls shall be compatible with handwear to be used in the anticipated environment. Unless otherwise specified, all dimensions cited herein are for bare hands and shall be revised where necessary for use with gloves or mittens.

23.7 Blind Operation—Where “blind” operation is necessary, hand controls shall be shape coded or separated from adjacent controls by at least 125 mm (5 in.).

23.8 Prevention of Accidental Actuation:

23.8.1 Location and Design—Controls shall be designed and located so that they are not susceptible to being moved accidentally, particularly critical or emergency controls whose inadvertent operation might cause damage to equipment, injury to personnel, or degradation of system functions.

23.8.2 Internal Controls—Internal or hidden controls shall be protected, because it is usually not obvious that such controls have been disturbed and it may be difficult and time consuming to locate and readjust them.

23.8.3 Rapid Operation—Any method of protecting a control from inadvertent operation shall not preclude operation within the time required.

23.8.4 Methods—For situations in which controls must be protected from accidental actuation, one or more of the following methods, as applicable, shall be used:

23.8.4.1 Locate and orient the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements.

23.8.4.2 Recess, shield, or otherwise surround the controls by physical barriers. The control shall be entirely contained within the envelope described by the recess or barrier.
FIG. 19 Control Motion Expectancy

A - CEILING
B - 45° PANEL
C - FRONT PANEL
D - DESK / CONSOLE SURFACE
E - UNDER CONSOLE
F - LEFT PANEL
G - RIGHT PANEL
23.8.4.3 Cover or guard the controls. Safety or lock wire shall not be used.

23.8.4.4 Provide the controls with interlocks so that extra movement (for example, a side movement out of a detente position or a pull-to-engage clutch) or the prior operation of a related or locking control is required.

23.8.4.5 Provide the controls with resistance (that is, viscous or coulomb friction, spring loading, or inertia) so that definite or sustained effort is required for actuation.

23.8.4.6 Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential activation is necessary (that is, the control moved only to the next position, then delayed).

23.8.4.7 Design the controls for operation by rotary action.

23.8.5 Dead Man Controls—Dead man controls, which will result in system shutdown to a noncritical operating state when force is removed, shall be used wherever operator incapacity can produce a critical system condition.

23.9 Foot-Operated Controls:

23.9.1 Use—Foot-operated controls may be used under the following conditions:

23.9.1.1 Control operation requires either greater force than the upper body can provide or force close to an upper body fatigue threshold.

23.9.1.2 The operator’s hands are generally occupied by other manual control tasks at the same moment that an additional control action is required.

23.9.1.3 A safety shutdown control is required during an operation in which the operator’s hands cannot be freed to reach a safety switch.

23.9.2 Avoidance—Foot-operated controls shall not be used under the following conditions:

23.9.2.1 Where a standing operator is confronted with a sensitive balancing requirement (for example, a moving platform where balancing on the nonoperating foot may become difficult as the operating foot is moved from a support to actuating position).

23.9.2.2 Precise control operations are required.

23.9.2.3 Selection from among a great many separate controls is required.

23.9.3 Operation—Foot controls shall be located and designed so they can be operated in as natural a pattern as practicable. Specifically, the following shall be avoided:

23.9.3.1 Frequent, maximum reaching.

23.9.3.2 Requirement to hold the leg or foot in awkward position for extended periods of time.

**TABLE 12 Minimum Separation Distances for Controls**

<table>
<thead>
<tr>
<th>Type of Coding</th>
<th>Location</th>
<th>Shape</th>
<th>Size</th>
<th>Model of Operation</th>
<th>Labeling</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toggle switches</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pushbuttons</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Continuous rotary controls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rotary selector switches</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**TABLE 13 Advantages and Disadvantages of Various Types of Coding**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Location</th>
<th>Shape</th>
<th>Size</th>
<th>Model of Operation</th>
<th>Labeling</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improves visual identification</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Improves nonvisual identification (tactual and kinesthetic)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Helps standardization</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>(when trans-illuminated)</td>
<td>X</td>
</tr>
<tr>
<td>Aids identification under low levels of illumination and colored lighting.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>(when trans-illuminated)</td>
<td>X</td>
</tr>
<tr>
<td>May aid in identifying control position (settings)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Requires little (if any) training: is not subject to forgetting.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**TABLE 14 Recommended Control Colors (FED-STD-595)**

<table>
<thead>
<tr>
<th>Use</th>
<th>Color</th>
<th>Gloss</th>
<th>Semi-Gloss</th>
<th>Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>black</td>
<td>17038</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>gray</td>
<td>...</td>
<td>26238</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>green</td>
<td>14187</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>orange-yellow</td>
<td>13538</td>
<td>23538</td>
<td>33538</td>
</tr>
<tr>
<td></td>
<td>white</td>
<td>17875</td>
<td>27875</td>
<td>37875</td>
</tr>
<tr>
<td>Supplement to</td>
<td>blue</td>
<td>15123</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>standard if</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>required</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency</td>
<td>red</td>
<td>11105</td>
<td>21105</td>
<td>31105</td>
</tr>
</tbody>
</table>

\(^A\) All values are for one hand operation. Distances are measured from edge to edge of each control.

\(^B\) For pushbuttons not separated by barriers.
23.9.3.3 Requirement for the operator to operate a control frequently or for an extended period of time while sitting in a twisted position, the pedals shall be laid out symmetrically with reference to the operator’s principal operating orientation.

23.9.3.4 Maximum force application frequently or for extended duration.

23.9.3.5 Requirement that the operator search for a particular foot control in order to select the proper one.

23.9.3.6 Placement of a foot control where it might be stepped on and inadvertently actuated or where typical shifting from one foot control to another creates conditions where the foot or clothing might be entrapped by an intervening control.

23.9.4 Configuration and Placement—Configuration and placement of foot operated controls shall accommodate the anthropometry of the operator’s foot wearing operational shoes or boots (See Section 30). They shall be located so that the activation of a control by one foot does not interfere with the activation of a control by another foot and so that the movements of feet and legs are natural and easily accomplished within the work station where foot controls are located.

23.9.5 Foot-Operated Switches:

23.9.5.1 Use—Foot-operated switches shall be used only where the operator is likely to have both hands occupied when switch activation may be required, or when load sharing among limbs is desirable. Because foot-operated switches are susceptible to accidental activation, their uses shall be limited to noncritical or infrequent operations such as press-to-talk communication or vehicle headlight dimming.

23.9.5.2 Operation—Foot switches shall be positioned for operation by the toe and the ball of the foot rather than by the heel. They shall not be located so near an obstruction that the operator cannot center the ball of the foot on the switch button. A pedal may be used over the button to aid in location and operation of the switch. When the switch may become wet and slippery, the switchcap surface shall possess a frictional surface to minimize the possibility of the foot slipping off the switch.

23.9.5.3 Dimensions, Resistance, and Displacement—Dimensions, resistance, and displacement of foot-operated switches shall conform to the criteria in Fig. 20. Although not recommended (only one switch per foot is preferred), when one foot is required to operate more than one switch, such switches shall be at least 75 mm (3 in.) apart (horizontal); 200 mm (8 in.) vertically.

![Diagram of Foot-Operated Switches](image)

**FIG. 20 Foot-Operated Switches**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Resistance</th>
<th>Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foot Will Not Be Actuated</td>
<td>Foot Will Be Actuated</td>
</tr>
<tr>
<td></td>
<td>Normal Operation</td>
<td>Heavy Boot Operation</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.5 mm (0.06 in.)</td>
<td>18 N (4 lbf)</td>
</tr>
<tr>
<td>Maximum</td>
<td>90 N (20 lbf)</td>
<td>65 mm (4 in.)</td>
</tr>
</tbody>
</table>

23.9.5.4 Feedback—A positive indication of control activation shall be provided (for example, snap feel, audible click, association visual, or auditory display).

23.10 Foot Pedals:

23.10.1 Use—Pedal controls shall be used only when the operator is likely to have both hands occupied when control operation is required or control system force is too high for manual force capability of the operator, or standardized use of pedals has created a stereotype expectancy (for example, vehicle pedal control configurations such as clutch, brake, accelerator, rudder).

23.10.2 Location—Pedal controls shall be located so that the operator can reach them easily without extreme stretching or torso twisting and can reach the maximally displaced pedals within anthropometric limits and force capabilities (see Fig. 21). Pedals that may be held or must be adjusted shall be located so the operator can “rest” and “steady” the foot, that is, the pedal shall be appropriate critical distance above the floor so the operator’s heel can rest on the floor while articulating the ankle/foot. When this cannot be done (and the pedal angle is more than 350 mrad (20°) from the horizontal floor), a heel rest shall be provided. Lateral spacing of individual pedals shall conform to criteria in Fig. 22. However, the overall array shall not exceed 760 mm (29 in.) as measured between the outermost pedal centerlines.

23.10.3 Control Return—Except for controls that generate a continuous output (for example, rudder controls), pedals shall return to the original null position without requiring assistance from the operator (for example, brake pedal). For pedals in which the operator may normally rest the foot on the control between operations, sufficient resistance shall be provided to prevent the weight of the foot from inadvertently actuating the control (for example, accelerator pedal).

23.10.4 Pedal Travel Path—The travel path shall be compatible with the natural articulation path of the operator’s limbs (that is, thigh, knee, ankle).

23.10.5 High-Force Application Aids—When foot controls requiring high control forces are to be used, the push force push exerted by the leg depends on the thigh angle and the knee angle. Fig. 23 specifies the mean maximum push at various knee and thigh angles. The maximum push is at about the 160° angle, referred to as the limiting angle of Fig. 23 apply to males only and shall be corrected for females. (Two thirds of each value is considered to be a reasonable value for females.) Appropriate aids shall be provided to assist the operator in applying maximum force including the following where applicable:

23.10.5.1 Seat backrest.

23.10.5.2 Optimized seat height-to-pedal and normal reach distance for maximum force, the seat reference point (SRP), and pedal are at the same vertical height.

23.10.5.3 Double-width pedal so that both feet can be used.

23.10.6 Non-slip Pedal Surface—Pedals used for high force applications shall be provided with a non-skid surface. Similar surfaces are desirable for all pedals.

23.10.7 Dimensions, Resistance, Displacement, and Separation—Dimensions, resistance, displacement, and separation of pedals shall conform to the criteria of Fig. 21.
23.10.8 Foot Controls Force (High)—Where foot controls requiring high control forces are to be used, the force push exerted by the leg depends on the thigh angle and knee angle. Fig. 23 specifies the mean maximum push at various knee and thigh angles. The maximum push is about the 160° angle, referred to as the limiting angle. The values of Fig. 23 apply to males only and shall be corrected for females. For females, use two thirds of the male value.
24. Rotary Controls

24.1 Discrete Rotary Controls:

24.1.1 Rotary Selector Switches—Rotary selector switches shall be used for discrete functions when three or more detented positions are required. Rotary selector switches shall not be used for a two-position function unless prompt visual identification of control position is of primary importance and speed of control operation is not critical.
24.1.2 Moving Pointer—Rotary selector switches shall be designed with a moving pointer and a fixed scale.

24.1.3 Shape—Moving pointer knobs shall be bar shaped, with parallel sides, and the index end shall be tapered to a
point. Exceptions may be justified when pointer knobs are shape coded or when space is restricted and torque is light. Shape coding shall be used when a group of rotary controls, used for different functions, is placed on the same panel and control confusion might otherwise result.

24.1.4 Positions—A rotary selector switch that is not visible to the operator during normal system operation shall have no more than 12 positions. A rotary switch that is constantly visible to the operator shall have not more than 24 positions. Recommended switch setting parameters are provided in Fig. 24. In addition, the following criteria shall apply:

24.1.4.1 Rotary switch positions shall not be placed opposite each other unless knob shape precludes confusion as to which end of the knob is the pointer.

<table>
<thead>
<tr>
<th>APPLICATION CRITERIA</th>
<th>DIMENSIONS</th>
<th>DISPLACEMENT</th>
<th>SEPARATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred for accurate identification of knob position by feel, control panels where high-force switches are not required, skirt optional</td>
<td>L = 38 mm to 100 mm (1 1/2 in to 3 1/2 in) if gloves are worn, add 13 mm (1/2 in)</td>
<td>H = 12 mm to 75 mm (1/2 in to 3 in)</td>
<td>MIN = 15° MIN, POS n ID = 30°, MAX = 60° for blind positioning, 90° for simultaneous operation of adjacent knobs (two hands); add 25 mm (1 in) for gloves</td>
</tr>
</tbody>
</table>

![Diagram of rotary selector controls](image)

**FIG. 24 Rotary Selector Controls**

43
24.1.4.2 The switch resistance shall be elastic, building up, then decreasing as each position is approached, so that the control snaps into position without stopping between adjacent positions.

24.1.4.3 Mechanical detentes shall be provided as the switch cannot be positioned in between nominal switch positions.

24.1.4.4 Stops shall be provided at the beginning and end of the range of control positions if the switch is not required to be operated beyond the end positions or specified limits (that is, if the switch is not a multirotation control, see 21.6).

24.1.5 Contrast—A reference line shall be provided on rotary switch controls. This line shall have at least 75% lumino contrast with the control color under all lighting conditions.

24.1.6 Parallax—The knob pointer shall be mounted sufficiently close to its scale to minimize parallax between the pointer and the scale markings. When viewed from the normal operator’s position, the parallax error shall not exceed 25% of the distance between scale markings.

24.1.7 Dimensions, Resistance, Displacement, and Separation—Rotary control dimensions, switch displacement, and control separation shall conform to criteria in Fig. 24 and Fig. 25.

24.1.8 Torque for Actuation—Actuating torque requirements shall be compatible with control knob sizes, that is, knob dimensions of 25 mm (1 in.) or less shall not require a torque of more than 350 N/m (Newton per metre) (2 lb-in) (pounds force per inch). Medium-sized knobs, 25 to 50 mm (1 to 2 in.), shall have a torque of less than 1050 N/m (6 lb-in). The larger knobs, diameters of 75 mm (3 in.), shall not require an actuation torque greater than 1576 M/m (9 lb-in).

24.2 Key-Operated Switches (KOS)—KOS are used to prevent unauthorized operation. Ordinarily, they control system operation by go no-go.

24.2.1 Dimensions, Displacement, and Resistance—Dimensions, displacement, and resistance shall conform to the criteria in Fig. 26 and Fig. 27.

24.2.2 Color, Shape, and Size Coding—Color, shape, or size coding or a combination may be used as follows:

24.2.2.1 Color may be used to aid in identifying various keys by function or use location and when illumination is adequate to differentiate the colors. Red shall be reserved for emergency functions.

24.2.2.2 Shape coding may be used when it is desirable to identify a given key by feel. When shape coding is used, sharp corners shall be avoided.

24.2.2.3 Size coding may be used as a valid discriminator such as shape if there are only two keys.

24.2.3 Marking and Labeling—Keylock switch applications shall include appropriate positional markings and labels (see Section 28).

24.2.4 Other Requirements:

24.2.4.1 Keys with teeth on both edges, which fit the lock with either side up or forward, are preferred.

24.2.4.2 Keys with a single row of teeth shall be inserted into the lock with the teeth pointing up or forward.

24.2.4.3 Locks shall be oriented so the key’s vertical position is the OFF position.

24.2.4.4 Operators shall normally not be able to remove the key from the lock unless the switch is turned OFF.

24.2.4.5 Activation of an item by a key-operated switch shall be accomplished by turning the key clockwise from the vertical OFF position.

24.3 Discrete Thumbwheel Controls—Thumbwheel controls may be used if the function requires a compact digital control-input device (for a series of numbers) and a readout of these manual inputs for verification. The use of thumbwheels for any other purpose is discouraged. Detente indexing units shall provide ten positions (0 to 9) in digital or binary (three or four bits and complement) outputs.

24.3.1 Shape—Each position around the circumference of a discrete thumbwheel shall have a concave surface or shall be separated by a high-friction area which is raised from the periphery of the thumbwheel. The thumbwheels shall not preclude viewing the digits within 30° viewing angle to the left and right of a perpendicular to the thumbwheel digits.

24.3.2 Coding—Thumbwheel controls may be coded by location, labeling, and color (for example, reversing the colors of the least significant digit wheel as on typical odometers). Where used as input devices, thumbwheel switch OFF or NORMAL positions shall be color coded to permit a visual check that the digits have been reset to their normal position.

24.3.3 Direction of Movement—Moving the thumbwheel edge forward, or upward, or to the right shall increase the setting (see Fig. 28).

24.3.4 Internal Illuminance of Numerals—For areas in which ambient illumination will provide display brightness below 3.5 cd/m² (1 ft-L), the thumbwheel shall be internally illuminated. Digits shall appear as light- or white-illuminated characters on a black background, and their dimensions shall approximate the following:

24.3.4.1 Height, 4.8 mm (5/16 in.).

24.3.4.2 Height-to-width ratio, 3:2.

24.3.4.3 Height-to-stroke width ratio, 10:1.

24.3.5 External Illuminance of Numerals—In areas in which ambient illumination will provide a display luminance above 3.5 cd/m² (1 ft-L), internal illumination is not required. Digits shall be bold, black numerals engraved on a light (or white) thumbwheel background. The dimensions shall approximate those specified in 24.3.4, except that the height-to-stroke width ratio shall be approximately 5:1.

24.3.6 Visibility—Thumbwheel design shall permit viewing of inline digital readout from all operator positions.

24.3.7 Dimensions—Control dimensions shall conform to the criteria in Fig. 29.

24.3.8 Resistance—Detentes shall be provided for discrete position thumbwheels. Resistance shall be elastic, building up and then decreasing as each detente is approached so that the control snaps into position without stopping between adjacent detentes. The resistance shall be within the limits indicated in Fig. 29.

24.3.9 Separation—The separation between adjacent edges of thumbwheel controls shall conform to the criteria in Fig. 29.
and shall be sufficient to preclude accidental activation of adjacent controls during normal setting.

24.4 Continuous Adjustment Rotary Controls:

24.4.1 Knobs—Knobs shall be used when low forces or precise adjustments of a continuous variable are required. A moving knob with fixed scale is preferred over a moving scale
24.4.2 Dimensions, Torque, and Separation—The dimensions of knobs shall be within the limits specified in Fig. 30. Within these ranges, knob size is relatively unimportant, provided the resistance is low and the knob can be easily grasped and manipulated. When panel space is extremely limited, knobs shall approximate the minimum values and shall have resistance as low as possible without permitting the setting to be changed by vibrations or by merely touching the control. Resistance and separation between adjacent edges of knobs shall conform to Fig. 30.

24.4.3 Shapes—Knobs that perform the same function shall have the same shape. The shape shall be determined by the knob's function and use. Representative knob shapes are shown in Fig. 31.

24.4.4 Tactual (Touch) Recognition—For knobs that must be recognized by touch alone, use easily recognizable knob shapes as shown in Fig. 32. Some sets of knobs have been specially developed and validated experimentally for tactual recognition.

24.4.5 Ganged Control Knobs—Ganged knob assemblies may be used in limited applications when panel space is at a premium. Two-knob assemblies are preferred. Three-knob configurations shall be avoided. Ganged knob configurations shall not be used under the following conditions:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>S-Separation</th>
<th>Resistance**</th>
<th>Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>13 mm (1/2 in)</td>
<td>13 mm (1/2 in)</td>
<td>20 mm (3/4 in)</td>
<td>25 mm (1 in)</td>
<td>0.1 N-m</td>
</tr>
<tr>
<td>Maximum</td>
<td>75 mm** (3 in)</td>
<td>38 mm* (1 1/2 in)</td>
<td>-</td>
<td>25 mm (1 in)</td>
<td>0.7 N-m</td>
</tr>
</tbody>
</table>

* Practical for carrying key in pocket.
** When locks are new.

FIG. 26 Keylock Criteria

with fixed index for most tasks. If positions of single revolution controls must be distinguished, a pointer or marker shall be available on the knob.

24.4.5.1 Extremely accurate or rapid operations are required.
24.4.5.2 Frequent changes are necessary.
24.4.5.3 Heavy gloves must be worn by the operator.
24.4.5.4 Equipment is exposed to the weather or used under field conditions.

24.4.6 Dimensions, Torque, and Separation—Dimensions, torque, and separation shall conform to Fig. 33.

24.4.7 Shapes—Knobs that perform the same function shall have the same shape. The shape shall be determined by the knob’s function and use. Representative knob shapes are shown in Fig. 31.

24.4.8 Tactual (Touch) Recognition—For knobs that must be recognized by touch alone, use easily recognizable knob shapes (Fig. 32).

24.4.9 Knob Serration—Knobs shall be serrated. Fine serrations shall be used on precise adjustment knobs; coarse serrations shall be used on gross adjustment knobs.

24.4.10 Marking—An indexing mark or pointer shall be provided on each knob. Marks or pointers shall differ sufficiently to make it apparent which knob indexing mark is being observed.

24.4.11 Detentes—Knob detentes placement shall conform to Table 15.

24.4.12 Knob/Display Relationship—When each knob of a ganged assembly must be related to an array of visual displays,
FIG. 27 Keylock Switch Criteria

Note 1 - Switchlocks should generally be oriented so that the pivotal off key position is vertical or forward, or both (for example, horizontal panel).

Note 2 - Key displacement between functional positions should be at least 0.53 rad (30°). Mechanical detents should preclude positioning the key in between designated positions.

Note 3 - When only two functional positions occur (that is, on-off), displacement between the two positions shall be 1.57 rad (90°).

Note 4 - Total displacement of multi-position keyswitches shall not exceed 2.09 rad (120°).

FIG. 28 Thumbwheel Orientation and Movement
the knob closest to the panel shall relate to the left-most display in a horizontal array, or the uppermost display in a vertical array.

24.4.13 Inadvertent Operation—When it is critical to prevent inadvertent actuation of one knob as the other is being adjusted, a secondary knob control movement shall be required (for example, pressing the top knob before it can be engaged with its control shaft). Where inadvertent movement is undesirable but not necessarily critical, knob diameter/depth relationships shall be optimized as shown in Fig. 33. Contrasting colors between knobs may also be used to improve individual knob identification.

24.4.14 Continuous Adjustment Thumbwheel Controls:

24.4.14.1 Use—Continuously adjustable thumbwheel controls may be used as an alternative to rotary knobs when the application will benefit from the compactness of the thumbwheel device.

24.4.14.2 Orientation and Movement—Thumbwheels shall be oriented and move in the directions specified in Fig. 34. If a thumbwheel is used as a continuous control that affects vehicle motion, movement of the thumbwheel forward or up shall cause the vehicle to move down or forward.

24.4.14.3 Turning Aids—The rim of the thumbwheel shall be serrated or provided with a high friction surface to aid the operator in manipulating the control.

24.4.14.4 Dimensions, Separation, and Resistance—Dimensions, separation and resistance shall conform to criteria in Fig. 34.

24.4.14.5 Labeling and Visibility—Marking and labeling shall conform to requirements herein, with respect to visibility of markings and legibility of label alphanumericics.

24.4.14.6 OFF Position—A detente shall be provided for continuous thumbwheels having an OFF position.

24.5 Cranks:

24.5.1 Use—Cranks shall be used for tasks requiring many rotations of a control, particularly where high rates or large forces are involved. For tasks involving large slowing movements, plus small, fine adjustments, a crank handle may be mounted on a knob or handwheel, with the crank for slowing and the knob or handwheel for fine adjustments. Where cranks are used for tuning, or other processes involving numerical selection, each rotation shall correspond to a multiple of 1, 10, 100, and so forth. Simultaneously operated handcranks shall be used in preference to other two-axis controllers where extreme precision is required in setting crosshairs or reticles as in map readouts or optical sighting mechanisms (as opposed to tracking). This type of control may also be used in other applications requiring x–y control provided there is no requirement for rapid or frequent operation. The gear ratio and dynamic characteristics of such cranks shall allow precise placement of the follower (for example, crosshairs) without overshooting or undershooting and successive corrective movements.

24.5.2 Grip Handle—The crank grip handle shall be designed so that it turns freely around its shaft.

24.5.3 Dimensions, Resistance, and Separation—Dimensions, resistance, and separation between adjacent swept circular areas of cranks shall conform to the criteria of Fig. 35.

24.5.4 Folding Handle—If a crank handle could become a hazard to persons passing by, or it is critical that the handle not be inadvertently displaced by being accidentally bumped, a folding handle-type control shall be used. Such a control shall be designed so that the handle is spring loaded to keep it extended in the cranking position when in use and folded when not in use.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Through Distance</th>
<th>Width</th>
<th>Depth</th>
<th>Separation</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>30 mm (1 1/8 in)</td>
<td>11 mm (7/16 in)</td>
<td>3 mm (1/8 in)</td>
<td>10 mm (13/32 in)</td>
<td>1.7 N (6 oz)</td>
</tr>
<tr>
<td>Maximum</td>
<td>75 mm (3 in)</td>
<td>19 mm (3/4 in)</td>
<td>13 mm (1/2 in)</td>
<td></td>
<td>5.6 N (20 oz)</td>
</tr>
</tbody>
</table>

FIG. 29 Discrete Thumbwheel Control
24.5.5 **Crank Balance**—In applications in which resistance is light, the crank shall be balanced to prevent the handle weight from turning the crank from its last setting.

24.5.6 **Positioning of Cranks**—Cranes that must be turned rapidly shall be mounted so their turning axis are between 60 and 90° from the frontal plane (Fig. 36). For standing operators, they shall be between 900 and 1200 mm (36 and 48 in.) above the floor.

24.6 **Handwheels**:

24.6.1 **Use**—Handwheels less than 152 mm (6 in.) in diameter shall be designed and located for one-handed operation. Handwheels greater than 152 mm (6 in.) shall be designed and located for two-handed operation. Handwheels designed for two-hand operation shall be used when the breakout or rotational forces are too high to be easily overcome with a one-handed control. Typical applications are steering, latch securing, valve opening/closing and direct-linkage adjustment.
24.6.2 Turning Aids—Knurling, indentation, high-friction covering, or a combination of these shall be built into the handwheel to facilitate operator grasp for applying maximum torque and to reduce the possibility of the wheel being jerked from the operator’s hands.

24.6.3 Spinner Handles—For applications in which the wheel may be rotated rapidly through several revolutions, a spinner handle may be added. Such handles shall not be used, however, if the projecting handle is vulnerable to inadvertent displacement of a critical wheel setting or if it creates a safety hazard.

24.6.4 Direction of Movement—Except for valves, handwheels shall rotate clockwise for ON or INCREASE and counterclockwise for OFF or DECREASE. The direction of motion shall be indicated on the handwheel, or immediately adjacent thereto, by means of arrow and appropriate legends. Valve handwheels shall turn counterclockwise to OPEN and clockwise to CLOSE. Direction of motion shall be indicated as stated above.

24.6.5 Dimensions, Resistance, Displacement, and Separation—Control dimensions, resistance, displacement, and separation between edges of adjacent handwheels shall conform to the criteria in Fig. 37.

24.6.6 Location—Where possible, valve handwheels shall be located as shown in Fig. 38 for valves mounted above the operators standing surface. Valve handwheels located below the standing surface (for example, below bilge deck grating), the handwheel shall be oriented parallel or perpendicular to the grating with the grasping surface of the handwheel no more than 300 mm (12 in.) below the standing surface. No valve handwheel larger than 510 mm (20 in.) in diameter shall be installed in the overhead above 1.93 m (77 in.) unless the operating force on the handwheel is less than 40 ft-lbf.

24.6.6.1 Access—Access to valve handwheels requiring one-handed operating from a bending, squatting, or standing ladder position shall not exceed the values shown in Fig. 39. Small valve handwheels installed on pipes wrapped with insulation shall be installed so there is a minimum of 50-mm (2-in.) clearance between the back of the handwheel and the insulation material. Handwheels associated with valves on strainers and filters shall be located so they are accessible with spray shields or enclosures in place. A minimum of 80-mm (3-in.) clearance on all sides of a handwheel shall be provided.

24.6.6.2 Position Indicators—Valves and handwheels equipped with mechanical position indicators shall be installed so the indicator is directly visible to the operator from the normal operating position.

24.6.6.3 Steering Wheel Shape—Except for established uses in applications in which maximum wheel deflection does not exceed ±2° (120°), all steering wheels shall be round.

25. Discrete Linear Controls

25.1 Push Buttons (Finger or Hand Operated):

25.1.1 Use—Push buttons shall be used when a control or an array of controls is needed for momentary contact or for activating a locking circuit, particularly in high-frequency-of-use situations.

25.1.2 Shape—The push-button surface shall normally be concave (indented) to fit the finger. When this is impractical, the surface shall provide a high degree of frictional resistance to prevent slipping.

25.1.3 Positive Indication—A positive indication of control activation shall be provided (snap feel, audible click, or integral light).

25.1.4 Channel or Cover Guard—A channel or cover guard shall be provided when it is imperative to prevent accidental activation of the controls. When a cover guard is in the open position, it shall not interfere with operation of the protected device or adjacent controls.

25.1.5 Dimensions, Resistance, Displacement, and Separation—Except for use of push buttons in keyboards, the control dimensions, resistance, displacement, and separation between adjacent edges of finger- or hand-operated push buttons shall conform to the criteria in Fig. 40.

25.1.6 Resistance—Single-finger, 2.8 N (10 oz) to 11 N (40 oz). Thumb or palm, 2.8 N (10 oz) to 23 N (80 oz).

25.1.7 Interlocks or Barriers—Mechanical interlocks or barriers may be used instead of the spacing required by Fig. 40.
25.1.8 **Identification/Legends**—Labels placed on the push-button face are preferred. Legends shall normally be legible with or without internal illumination. A lamp test capability or a dual lamp reliability, or both, shall be provided, except for switches using LEDs in place of incandescent lamps. Other considerations include:

25.1.8.1 No more than three lines of lettering shall normally be used on a legend plate.

25.1.8.2 Lamps shall be replaceable from the front of the panel, by hand, and the legend or cover plate shall be keyed to prevent possibility of interchanging covers.

25.2 **Keyboards**:

25.2.1 **Use**—Arrangements of push buttons in the form of keyboards shall be used when alphabetic, numeric, or special function information is to be entered into a system.

25.2.2 **Layout and Configuration**—The key configuration and the number of keys are dependent upon the predominant type of information to be entered into the system. The major forms that keyboards can take, which aid in the entry of such information, are given below:

25.2.2.1 **Numeric Keyboard**—The configuration of a keyboard used to enter solely numeric information shall be a $3 \times 3 + 1$ matrix with the zero digit entered on the bottom row and

<table>
<thead>
<tr>
<th>Number of Settings</th>
<th>Recommended Starting Position, ( \text{rad} ) (degrees)</th>
<th>Recommended Angular Displacement, ( \text{rad} ) (degrees)</th>
<th>Recommended Radius for 13-mm Separation, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.28 (16.00)</td>
<td>4.59 (264.00)</td>
<td>0.70 (40.00)</td>
</tr>
<tr>
<td>4</td>
<td>0.63 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>5</td>
<td>0.65 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>6</td>
<td>0.63 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>7</td>
<td>0.61 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>8</td>
<td>0.59 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>9</td>
<td>0.57 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>10</td>
<td>0.55 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>11</td>
<td>0.54 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
<tr>
<td>12</td>
<td>0.52 (237.33)</td>
<td>4.98 (243.31)</td>
<td>19.5 (773)</td>
</tr>
</tbody>
</table>

* To and including 25 mm (1 in) diameter knobs.
** Greater than 25 mm (1 in) diameter knobs.
arranged in either of the following ways:
123 456 789 0 or 789 456 123 0

25.2.2.2 Alphanumeric Keyboard—Keyboard configurations can vary with the entry of data changing from primarily alphabetic to primarily numeric. For these applications, two alternatives are preferred: provide a keyboard where there is no separation between alphabetic and numeric characters or provide a separation to emphasize the two separate functions, with the numeric keyboard located to the right of the standard keyboard.

25.2.2.3 Dimensions, Resistance, Displacement, and Separation—The control dimensions, resistance, displacement, and separation between adjacent edges of the push buttons which form keyboards shall conform to the criteria in Table 16 and Table 17. For a given keyboard, these criteria shall be uniform for all individual keys. For those applications in which operation while wearing (trigger finger) arctic mittens is required, the minimum key size shall be 19 mm (0.75 in.). Other parameters are unchanged from those of bare-handed operation (see Table 16 and Table 17).

25.2.2.4 The slope of nonportable keyboards shall be 260 to 435 mrad (15 to 25°) from the horizontal. The preferred slope is 280 to 300 mrad (17 to 18°). The slope of a portable device can be varied according to the preference of the operator. The first row of keys shall be between 230 and 300 mm (9 and 12 in.) above the seat level.

25.2.2.5 Multiple Keyboards—Systems containing more than one keyboard shall maintain the same configuration for alphanumeric, numeric, and special function keys throughout the system.

25.2.2.6 Feedback—Feedback shall be provided to inform the operator whether the key was pressed, the intended key was pressed, and whether the next operation may be initiated.

25.3 Toggle Switch Controls:
25.3.1 Use—Toggle switches shall be used for functions that require two discrete positions or where space limitations

![FIG. 34 Thumbwheel Adjustment Controls](image)

<table>
<thead>
<tr>
<th>E</th>
<th>W</th>
<th>S</th>
<th>RESISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>MINIMUM</td>
<td>25 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td></td>
<td>(1 in)</td>
<td>(1/8 in)</td>
<td>(1 in) 2 Add 13 mm (1/2 in) for gloves</td>
</tr>
<tr>
<td></td>
<td>MAXIMUM</td>
<td>100 mm</td>
<td>23 mm</td>
</tr>
<tr>
<td></td>
<td>(4 in)</td>
<td>(7/8 in)</td>
<td></td>
</tr>
</tbody>
</table>

* Preferred. Some miniature applications may require less.
are severe. Toggle switches with three positions shall be used only where the use of a rotary control, legend switch control, and so forth, is not feasible or when the toggle switch is of the spring-loaded, center position-off type. Three position toggle switches that are spring loaded to center-off from only one other position shall not be used if release from the spring-loaded position results in switch handle travel beyond the off position. Toggle switches are considered herein to be discrete position controls. Small controls that are the same size and shape as toggle switches and used for making continuous adjustments are described herein as levers.

25.3.2 Accidental Activation—When the prevention of accidental activation is of primary importance (critical, dangerous, or hazardous conditions would result), channel guards, lift-to-unlock switches, or other equivalent prevention mechanisms shall be provided. Safety or lock wire shall not be used. Resistance of lift-to-unlock mechanisms shall not exceed 13 N.
25.4.3.4 Lamps within the legend switch shall be replaceable from the front of the panel by hand and the legends or covers shall be keyed to prevent the possibility of interchanging the legend covers.

25.4.3.5 There shall be a maximum of three lines of lettering on the legend plate.

25.5 **Rocker Switches:**

25.5.1 **Use**—Rocker switches may be used in lieu of toggle switches for functions that require two discrete positions. They may be used for applications in which toggle switch handle protrusions might snag the operator’s sleeve or phone cord or there is insufficient panel space for separate labeling of switch positions. Rocker switches with three positions shall be used only where the use of a rotary control, legend switch control, and so forth, is not feasible or when the rocker switch is of the spring-loaded center-off type.

25.5.2 **Accidental Actuation**—When the prevention of accidental actuation is of primary importance (critical, dangerous, or hazardous conditions would result), channel guards or equivalent protective measures shall be provided.

25.5.3 **Positive Indication**—An indication of control activation shall be provided (snap feel, audible click, associated or integral light).

25.5.4 **Dimensions, Resistance, Displacement, and Separation**—Dimensions, resistance, displacement, and separation between adjacent edges of rocker switches shall conform to the criteria in Fig. 43. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions. Resistance for a small switch ranges from 2.8 N (10 oz) minimum to 4.5 N (16 oz) maximum. For large switches, the forces are 2.8 N (10 oz) minimum to 11 N (40 oz) maximum.

25.5.5 **Orientation**—Rocker switches may be used in lieu of toggle switches for functions that require two discrete positions. They may be used for applications in which toggle switch handle protrusions might snag the operator’s sleeve or phone cord or there is insufficient panel space for separate labeling of switch positions. Rocker switches with three positions shall be used only where the use of a rotary control, legend switch control, and so forth, is not feasible or when the rocker switch is of the spring-loaded center-off type.

25.5.6.1 Height, 4.8 mm (1/16 in.).

25.5.6.2 Height-to-width ratio, 3:2.

25.5.6.3 Height-to-stroke-width ratio, 10:1.

25.6 **Slide Switch Controls:**

25.6.1 **Use**—Slide switch controls may be used for functions that require two discrete positions. Slide switch controls may also be used for functions that require a higher number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (for example, audio settings across frequencies), but shall not be used where mispositioning is to be avoided.

25.6.2 **Accidental Actuation**—When the prevention of accidental actuation is of primary importance (critical, dangerous,
or hazardous conditions would result), channel guards or other equivalent means shall be provided.

25.6.3 Dimensions, Resistance, and Separation—Dimensions, resistance, and separation of slide switch handles shall conform to criteria in Fig. 45. Detentes shall be provided for each control setting. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of stopping between positions.

25.6.4 Orientation—Where practicable, slide switches shall be vertically oriented with movement of the slide up or away from the operator turning the equipment or component on, causing a quantity to increase, or causing the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation or actuation slide switches shall be used only for compatibility with the controlled function or equipment location.

25.6.5 Positive Indication—Slide switch controls involving more than two positions shall be designed to provide positive indication of control setting, preferably a pointer located on the left side of the slide handle.

25.7 Discrete Push-Pull Controls:

25.7.1 Applications—Push-pull controls may be used when two discrete functions are to be selected. However, such applications should be used sparingly. They may also be used in certain cases in which limited panel space suggests a miniaturized knob that may be used to serve two related, but distinct, functions (such as an ON-OFF/volume switch for a TV monitor). A three-position push-pull control is acceptable in isolated instances in which the criticality of inadvertent selection of the wrong position has no serious consequences.

25.7.2 Handle Dimensions, Displacement, and Clearances—Push-pull control handles shall conform to criteria in Fig. 46.

25.7.3 Rotation—Except for combination push-pull/rotate switch configurations, push-pull control handles shall be keyed to a nonrotating shaft, unless the control is to be used for a
special application (for example, the handle is rotated to disengage the brake setting). When the control system provides a combination push-pull/rotate functional operation, using a round style knob, the rim of the knob shall be serrated to denote (visually and tactually) that the knob can be rotated and to facilitate a slip-free finger grip.

25.7.4 Detentes—Mechanical detentes shall be incorporated into push-pull controls to provide tactile indication of positions.

25.7.5 Snagging and Inadvertent Contact—Use, location, and operating axis of push-pull-type controls shall preclude the possibility of the operator(s):

25.7.5.1 Bumping a control while getting into or out of position.

25.7.5.2 Snagging clothing, communication cables, or other equipment items on the control.

25.7.5.3 Inadvertently deactuating the control setting while reaching for another control.

25.7.6 Direction of Control Motion—Control direction shall be as follows:

25.7.6.1 Pull the operator for ON or actuation; push away for OFF or deactuation.

25.7.6.2 Clockwise for deactuation or increasing function of combination pull/rotary switches.
<table>
<thead>
<tr>
<th>APPLICATION CRITERIA</th>
<th>DESIGN CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DIMENSIONS</td>
</tr>
<tr>
<td>PANEL-MOUNTED PUSH Buttons: Single finger. One button at a time. Non-legend or buttons that require only a single number on the front surface may be round, square or rectangular</td>
<td>FINGERTIP D - MIN 10 mm (3/8 in) D-MAX 25 mm (1 in)</td>
</tr>
<tr>
<td>A CONCAVE SURFACE MAY BE USED TO AID FINGER-CENTERING (NON-GLOVE OPN ONLY).</td>
<td>D-MAX 19 mm (3/4 in) D-MIN 13 mm (1/2 in)</td>
</tr>
<tr>
<td>RECESSED BUTTON TO MINIMIZE INADVERTENT END OPERATION. TAPERED &quot;WELL&quot; GUIDES FINGER.</td>
<td>OPENING 19 mm (3/4 in) D-MIN WELL 32 mm (1 1/4 in) WITH GLOVES</td>
</tr>
<tr>
<td>PREVENT INADVERTENT OPERATION OF CRITICAL SWITCH, EITHER WITH GUARD RING, OR PANEL WELL.</td>
<td>SAME AS ABOVE</td>
</tr>
<tr>
<td>HANDLE, END-MOUNTED, PUSH BUTTON SWITCH. INDEX FINGER-OPERATED. RECESS TO PRECLUDE INADVERTENT OPERATION.</td>
<td>D-MINIMUM DIAM 10 mm (3/8 in)</td>
</tr>
<tr>
<td>THUMB-OPERATED</td>
<td>D-MINIMUM 13 mm (1/2 in)</td>
</tr>
<tr>
<td>ALTERNATE FINGER OR HEEL OF THE HAND OPERATION. CONVEX SURFACE DESIRABLE.</td>
<td>D - MIN 25 mm (1 in)</td>
</tr>
<tr>
<td>GRIP HANDLE SWITCH ALTERNATE MULTI-FINGER OR PALM OPERATION</td>
<td>W-MIN 6.5 mm (1/4 in) L - PREFERRED MIN 25 mm (1 in)</td>
</tr>
<tr>
<td>GANGED PUSH BUTTON ASSEMBLY SQUARE, RECTANGULAR OR ROUND SHAPES ARE ACCEPTABLE. DEPRESSION OF ANY BUTTON SHALL CAUSE ANY PREVIOUSLY DEPRESSED BUTTON TO RETURN TO DEACTIVATED POSITION. NUMBERED BUTTONS SHALL PROGRESS AS ILLUSTRATED.</td>
<td>W OR D-MIN 13 mm (1/2 in) FOR GLOVES</td>
</tr>
</tbody>
</table>

* For miniaturized applications, diameters as small as 3.2 mm (1/8 in) may be used subject to approval by the procuring activity.

FIG. 40 Pushbutton Switches
25.7.7 Resistance—Force for pulling a panel control with fingers shall be not more than 18 N (4 lbs), for pulling a T-bar with four fingers shall be not more than 45 N (10 lbs).

25.8 Printed Circuit (PC) Switch Controls:

25.8.1 Use—PC switches may be used when manual programming functions are required in systems using printed circuit boards.

25.8.2 Dimensions, Resistance, Displacement, and Separation—Dimensions, resistance, displacement, and separation between adjacent PC switch actuators shall conform to the following:

25.8.2.1 Dimensions of actuators shall be sufficiently high to permit error-free manipulation by the operator when using some commonly available stylus (for example, a pencil or a pen). The design of the actuators shall not require the use of a special tool for manipulation.

25.8.2.2 Actuator resistance shall be sufficiently high to avoid inadvertent actuation under expected use conditions. Resistance shall gradually increase, then drop when the actuator snaps into position. The actuator shall not be capable of stopping between positions.

25.8.2.3 When actuators are slide type, they shall have sufficient travel (displacement) to permit easy recognition of switch setting. At a minimum, the travel shall be twice the length of the actuator. When actuators are rocker type, the actuated wing shall be flush with the surface of the module.

25.8.2.4 Actuators shall have sufficient separation to permit error-free manipulation by the operator (the stylus cannot inadvertently contact adjacent actuators).

25.8.3 Shape—The surface of the actuator shall be indented to accept the point of the stylus. The indentation shall be sufficiently deep to avoid slippage of the stylus during manipulation.

26. Continuous Adjustment Linear Controls

26.1 Levers:

26.1.1 Use—Levers may be used when large amounts of force or displacement are involved or when multidimensional movements of controls are required.

26.1.2 Coding—When several levers are grouped in proximity to each other, the lever handles shall be coded.

26.1.3 Labeling—When practicable, all levers shall be labeled as to function and direction of motion.

26.1.4 Limb Support—When levers are used to make fine or continuous adjustments, support shall be provided for the appropriate limb segment as follows:

26.1.4.1 For large hand movements, elbow support.

26.1.4.2 For small hand movements, forearm support.

26.1.4.3 For finger movements, wrist support.

26.1.5 Dimensions—The length of levers shall be determined by the mechanical advantage needed. When the lever or grip handle is spherical, its diameter shall conform to the criteria in Fig. 47. When the levers are of the slide type, dimensions and separations shall comply with Fig. 48.

26.1.6 Resistance—The resistance incorporated in levers shall be within the limits indicated in Fig. 47 and Fig. 48 measured as linear force applied to a point on the handle.

Note 1: The right hand can supply slightly more force than the left, but the difference is not significant. The same amount of push-pull force can be applied when the control is along the median plane of the body as when it is directly in front of the arm, 180 mm (7 in.) from the median plane. When the control is placed in front of the opposite (unused) arm, only 75% as much force can be applied. When the control is 250 to 480 mm (10 to 19 in.) forward of the neutral seat reference point, twice as much push-pull force can be applied with two hands as with one-hand operation. Outside this range, two-hand operation becomes less effective.

26.1.7 Elastic Resistance—For joystick controls, elastic resistance that increases with displacement may be used to improve stick feel.

26.1.8 Displacement and Separation—Control displacement (for the seated operator) and separation shall conform to the criteria in Fig. 47.

26.2 Displacement Joysticks—(also known as Isotonic Joysticks.) Displacement joysticks usually have a spring resistance to movement away from the center (null) position, although some have no spring. Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. (The term “joystick” is used here to refer primarily to controls used for cursor placement or precise adjustment.) When positioning accuracy is more critical than...
positioning speed, displacement joysticks shall be selected over isometric joysticks. Displacement joysticks may also be used for various display functions such as data pickoff from a CRT and generation of free-drawn graphics. In rate control applications, which allow the follower (cursor or tracking symbol) to transit beyond the edge of the display, indicators shall be provided to aid the operator in bringing the follower back onto the display. Displacement joysticks that are used for rate control shall be spring loaded for return to the center when the hand is removed. Displacement joysticks that have a

<table>
<thead>
<tr>
<th>APPLICATION CRITERIA</th>
<th>DESIGN CRITERIA</th>
<th>DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINIATURE TOGGLE SWITCH: LIMIT USE TO INDOOR APPLICATIONS WHERE LIMITED PANEL SPACE PRECLUDES STD SIZE COMPONENTS.</td>
<td>W - MIN DIAM = 3.3 mm (.13 in)</td>
<td>L - MIN LENGTH = 13 mm (1/2 in)</td>
</tr>
<tr>
<td>STANDARD CONFIGURATION: USE LARGER SIZES FOR APPLICATIONS WHERE GLOVED OPERATION IS LIKELY.</td>
<td>W - MIN DIAM = 4.5 mm (.18 in) MAX = 7.8 mm (.31 in)</td>
<td>LENGTH MIN = 13 mm (1/2 in) MAX = 50 mm (2 in)</td>
</tr>
<tr>
<td>BALL CAP DESIGN APPLICABLE WHERE FIRM GRASP OF TOGGLE IS NEEDED DUE TO VEHICLE/OPTION OSCILLATION.</td>
<td>W - MIN BAL DIAM = 4.5 mm (.18 in) MAX = 7.8 mm (.31 in)</td>
<td>SAME AS ABOVE</td>
</tr>
<tr>
<td>FLAT OR APPLIED TAB HANDLES PROVIDE IMPROVED VISUAL POSITION REFERENCE WHEN OPERATIONALLY IMPORTANT.</td>
<td>W - MIN HANDLE WIDTH = 4.5 mm (.18 in)</td>
<td></td>
</tr>
<tr>
<td>APPLIED TAB HANDLE PROVIDES MEANS FOR COLOR CODING.</td>
<td>W - 10 mm (40 in) PREFERRED MAX = 25 mm (1 in)</td>
<td>W - 10 mm (.40 in) PREFERRED MIN = 4.8 mm (.19 in) MZX = 18 mm (1.5 in)</td>
</tr>
<tr>
<td>ALTERNATE TO ANY STD SIZE CONFIGURATION ABOVE</td>
<td></td>
<td>SAME AS ABOVE</td>
</tr>
</tbody>
</table>

FIG. 41 Toggle Switches
deadband near the center or hysteresis shall not be used with automatic sequencing of a CRT follower (cursor or tracking symbol) unless they are instrumented for null return or zero set to the instantaneous position of the stick at the time of sequencing. Upon termination of the automatic sequencing routine, joystick center shall again be registered to scope center. Displacement joysticks usually require less force than isometric joysticks and are less fatiguing for long operating periods.

26.2.1 Hand-Operated Displacement Joysticks:

26.2.1.1 Specific Use—In addition to the general use, hand-operated displacement joysticks may be used as vehicle controllers and aiming sensors. Hand-operated displacement joysticks may be used as mounting platforms for secondary controls, such as thumb- and finger-operated switches. Operation of secondary controls has less induced error on the displacement hand grip than does isometric handgrips.

26.2.1.2 Dynamic Characteristics—Movement shall not exceed 45° from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. When used for generation of free-drawn graphics, the refresher rate for the follower on
the CRT shall be sufficiently high to give the appearance of a continuous track. Delay between control movement and confirming display response shall be minimized and shall not exceed 0.1 s.

26.2.1.3 Dimensions, Resistance, and Clearance—The hand grip length shall be in the range of 110 to 180 mm (4.3 to 7.1 in.). The grip diameter shall not exceed 50 mm (2 in.). Clearances of 100 mm (4 in.) to the side and 50 mm (2 in.) to the rear shall be provided to allow for hand movement. Joysticks shall be mounted to provide forearm support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.
26.2.2 Finger-Operated Displacement Joysticks:

26.2.2.1 Specific Use—In addition to the general uses, finger-operated displacement joysticks are useful for free-drawn graphics. In this application, there is usually no spring return to center, and the resistance shall be sufficient to maintain the handle position when the hand is removed.

26.2.2.2 Dynamic Characteristics—Movement shall not exceed 45° from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. Recessed mounting or pencil attachments may be used as indicated in Fig. 49 to provide greater precision of control. When used for generation of free-drawn graphics, the refresher rate for the follower on the CRT shall be sufficiently high to give the appearance of a continuous track. Delay between control movement and the confirming display response shall be minimized and shall not exceed 0.1 s.

26.2.2.3 Dimensions, Resistance, and Clearance—The joystick shall be mounted on a desk or shelf surface as shown in Fig. 49. Joysticks shall be mounted to provide forearm or wrist support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.3 Thumbtip/Fingertip-Operated Displacement Joysticks:

26.2.3.1 Specific Use—Thumbtip/fingertip-operated joysticks may be mounted on a handgrip, which serves as a steady rest to damp vibrations and increase precision. If so mounted, the handgrip shall not simultaneously function as a joystick controller.

26.2.3.2 Dynamic Characteristics—Movement shall not exceed 785 rad (45°) from the center position.

26.2.3.3 Dimensions, Resistance, and Clearance—Joysticks shall be mounted to provide wrist or hand support. Console mounted devices shall be mounted as shown in Fig. 49. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.4 Isometric Joystick (Two-Axis Controllers)—Also known as stiff stick, force stick, or pressure stick. The controller has no perceptible movement, but its output is a function of force applied. Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. Isometric joysticks are particularly appropriate for applications: (1) which require precise return to center after each use; (2) in which operator feedback is primarily visual rather than tactile feedback from the control itself; and (3) where there is minimal delay and tight coupling between control and input and system reaction. Isometric sticks shall ordinarily not be used in applications in which it would be necessary for the operator to maintain a constant force on the control for a long period of time or in which there is no definitive feedback when maximum control inputs have been exceeded. Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. When positioning speed is more critical than positioning.
accuracy, isometric joysticks shall be selected over displacement joysticks. Isometric joysticks may also be used for various display functions such as data pickup from a CRT. In rate control applications, which may allow the follower (cursor or tracking symbol) to transit beyond the edge of the display, indicators shall be provided to aid the operator in bringing the follower back onto the display.

26.2.4.1 Hand Operated:

(a) Specific Use—In addition to the general use, hand-operated isometric joysticks may be used as vehicle controllers and aiming sensors. Hand-operated isometric joysticks may be used as mounting platforms for secondary controls, such as thumb- and finger-operated switches. Operation of secondary controls has greater induced error on the isometric hand grip than does displacement handgrip joysticks.

(b) Dynamic Characteristics—Maximum force for full output shall not exceed 118 N (26.7 lbs).

(c) Dimensions, Resistance, and Clearance—The hand grip length shall be in the range of 110 to 180 mm (4.3 to 7.1 in.). The grip diameter shall not exceed 50 mm (2 in.). Clearances of 100 mm (4 in.) to the side and 50 mm (2 in.) to the rear shall be provided to allow for hand movement. Joysticks shall be mounted to provide forearm support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.4.2 Finger-Operated Displacement Joysticks:

(a) Specific Use—In addition to the general uses, finger-operated displacement joysticks are useful for free-drawn graphics. In this application, there is usually no spring return to center, and the resistance shall be sufficient to maintain the handle position when the hand is removed.

(b) Dynamic Characteristics—Movement shall not exceed 785 mrad (45°) from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. Recessed mounting or pencil attachments may be used to provide more precise control. When used for generation of free-drawn graphics, the
refresher rate for the follower on the CRT shall be sufficiently high to give the appearance of a continuous track. Delay between control movement and the confirming display response shall be minimized and shall not exceed 0.1 s.

(c) Dimensions, Resistance, and Clearance—The joystick shall be mounted on a desk or shelf surface as shown in Fig. 49. Joysticks shall be mounted to provide forearm or wrist support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.4.3 Thumbtip/Fingertip-Operated:

(a) Specific Use—Thumbtip/fingertip-operated joysticks may be mounted on a handgrip, which serves as a steady rest to damp vibrations or increase precision. If so mounted, the handgrip shall not simultaneously function as a joystick controller.

(b) Dynamic Characteristics:

(c) Dimensions, Resistance, and Clearance—Joysticks shall be mounted to provide wrist or hand support. Console mounted devices shall be mounted as shown in Fig. 49. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.
26.3 Ball Control (Also Known as Track Ball, Ball Tracker, Joyball, and Rolling Ball):

26.3.1 Use—A ball control suspended on low-friction bearings may be used for various control functions such as data pickoff on a display. The ball control cannot provide an automatic return to point of origin, hence if used in applications requiring automatic return to origin following an entry or readout, the interfacing system must provide this. Because the ball can be rotated within limit in any direction, it is well suited for applications in which there may be accumulative travel in a given direction. In any application that would allow the ball to drive the follower on the display off the edge of the display, indicators shall be provided to advise the operator how to bring the follower back onto the display. Ball controls shall be used only as position controls (that is, a given movement of a ball makes a proportional movement of the follower on the display).

26.3.2 Dynamic Characteristics—The ball control shall be capable of rotation in any direction so as to generate any combination of x and y output values. When moved in either the x or y directions alone, there shall be no apparent cross coupling (follower movement in the orthogonal direction). While manipulating the control, neither backlash nor cross coupling shall be apparent to the operator. Control ratios and dynamic features shall meet the dual requirement of rapid gross positioning and smooth, precise fine positioning.

26.3.3 Limb Support—When trackball controls are used to make precise or continuous adjustments, wrist support or arm support or both shall be provided.

26.3.4 Dimensions, Resistance, and Clearance—Dimensions, resistance, and clearances shall conform to the criteria in Fig. 50. The smaller diameter ball controls shall be used only where space availability is very limited and when there is no need for precision. Preferred mounting is on a shelf or desk top.

26.4 Grid-and-Stylus Devices—These provisions cover various techniques that use some means of establishing an x and y grid and a stylus for designating specific points on that grid for control purposes (time-shared x and y potential grids and a voltage-sensitive stylus).

26.4.1 Application—Grid and stylus devices may be used for data pickoff from a CRT, entry of points on a display,
generation of free-drawn graphics, and smaller control applications. The grid may be on a transparent medium allowing stylus placement directly over corresponding points on the display or it may be displaced from the display in a convenient position for stylus manipulation. In either case, a follower (bug, mark, hook, and so forth) shall be presented on the display at the coordinate values selected by the stylus. Devices of this type shall be used only for zero order control functions (that is, displacement of the stylus from the reference position causes a proportional displacement of the follower).

26.4.2 Dynamic Characteristics—Movement of the stylus in any direction on the grid surface shall result in smooth movement of the follower in the same direction. Discrete placement of the stylus at any point on the grid shall cause the follower to appear at the corresponding coordinates and to remain steady in position so long as the stylus is not moved. Refresh rate for the follower shall be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used for generation of free-drawn graphics.

26.4.3 Dimensions and Mounting—Transparent grids that are used as display overlays shall conform to the size of the display. Grids that are displaced from the display shall approximate the display size and shall be mounted below the display in an orientation to preserve directional relationships to the display.
maximum extent (a vertical plane passing through the north/south axis on the grid shall pass through or be parallel to the north/south axis on the display).

26.5 Free-Moving X-Y Controller (Mouse):

26.5.1 Application—This type of controller may be used on any flat surface to generate $x$ and $y$ coordinate values that control the position of the follower on the associated display. It may be used for data pickoff or for entry of coordinate values. It shall be used for zero order control only (generation of $x$ and $y$ outputs by the controller results in proportional displacement of the follower). It shall not be used for generation of free-drawn graphics.

26.5.2 Dynamic Characteristics—The design of the controller and placement of the maneuvering surface shall be such as to allow the operator to consistently orient the controller to within $\pm 175$ mrad ($10^\circ$) of the correct orientation without

<table>
<thead>
<tr>
<th>DIMENSIONS</th>
<th>RESISTANCE</th>
<th>CLEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D DIAM</td>
<td>A SURFACE EXPOSURE</td>
<td>PRECISION REQUIRED</td>
</tr>
<tr>
<td>MINIMUM</td>
<td>50 mm (2 in)</td>
<td>1745 mrad (100°)</td>
</tr>
<tr>
<td>MAXIMUM</td>
<td>150 mm (6 in)</td>
<td>2445 mrad (140°)</td>
</tr>
<tr>
<td>PREFERRED</td>
<td>100 mm (4 in)</td>
<td>2095 mrad (120°)</td>
</tr>
</tbody>
</table>

FIG. 50 Ball Controls
visual reference to the controller. (That is, for example, when the operator grasps the controller in what seems to be the correct orientation and moves it rectilinearly along what is assumed to be straight up the y axis, then the direction of movement of the follower on the CRT shall be between 175 and 6110 mrad (10° and 350°).) The controller shall be easily moveable in any direction without a change of hand grasp and shall result in smooth movement of the follower in the same direction ±175 mrad (10°). The controller shall be cordless and shall be operable with either the left or right hand. A complete excursion of the controller from side to side of the maneuvering area shall move the follower from side to side on the display regardless of scale setting or offset unless expanded movement is selected for an automatic sequencing mode of operation. In any application that would allow the controller to drive the follower off the edge of the display, indicators shall be provided to assist the operator in bringing the follower back onto the display.

26.5.3 Dimensions and Shape—The free-moving x-y controller shall have no sharp edges but shall be shaped roughly as a rectangular solid, with limiting dimensions as given in Table 18.

26.6 Light Pen:

26.6.1 Use—A simple light pen may be used as a track-oriented readout device. That is, it may be positioned on the display screen to detect the presence of a computer-generated track by sensing its refresh pattern; the display system will then present a follower (hook) on the designed track. With suitable additional circuitry, a follower can be made to track the movement of the light pen across the surface, thus allowing it to function as a two-axis controller capable of serving the same purposes as the grid and stylus devices (see 26.4, Grid and Stylus Devices).

26.6.2 Dynamic Characteristics—When used as a two-axis controller, light pen dynamic characteristics shall conform to 26.5.2.

26.6.3 Dimensions and Mounting—The light pen shall be 120 to 180 mm (4.7 to 7.1 in.) long with a diameter of 7 to 20 mm (0.3 to 0.8 in.). A convenient clip shall be provided at the lower right side of the CRT to hold the light pen when it is not in use.

26.7 High-Force Controls:

26.7.1 Use—In general, controls requiring operator forces exceeding the strength limits of the lowest segment of the expected user population shall not be used. In addition, high-force controls shall not be used except when the operator’s nominal working position provides proper body support or limb support or both, such as, seat backrests, foot supports. Sustained (durations longer than 3 s) high-force requirements shall be avoided.

26.7.2 Arm-, Hand-, and Thumb-Finger Controls—Where arm-, hand-, and thumb-finger controls requiring high-control forces are to be used, the maximum force requirements shall not exceed those specified in Table 19 and Table 20, which shall be corrected, where applicable, for females. (Two thirds of each value shown is considered to be a reasonable adjustment.)

26.7.3 Foot Controls—Where foot controls requiring high-control forces are to be used, the force push exerted by the leg depends on the thigh angle and knee angle. Fig. 21 specifies the mean maximum push at various knee and thigh angles. The maximum push is about the 160° angle, referred to as the limiting angle. The values of Fig. 21 apply to males only and shall be corrected for females. (Two thirds of each value is considered to be a reasonable adjustment.)

26.8 Touch-Screen Controls for Displays:

26.8.1 Use—Touch-screen control may be used to provide an overlaying control function to a data display device such as CRTs, dot matrix/segmented plays, electroluminescent displays, programmable indicators, or other display devices in which direct visual reference access and optimum direct control access are desired.

26.8.2 Luminance Transmission—When used, touch-screen displays shall have sufficient luminance transmission to allow the display with touch screen installed to be clearly readable in the intended environment and meet the display luminance requirements herein.

26.8.3 Positive Indication—A positive indication of touch-screen activation shall be provided to acknowledge the system response to the control action.

26.8.4 Dimensions and Separation—The dimensions and separation of responsible areas of the touch screen shall conform to S1, S2, and Bw of Fig. 43.

26.8.5 Pressure—The actuation pressure of the touch screen shall conform to the alphanumeric resistance limits of Table 15.

26.8.6 Resistance—Force required to operate force-actuated touch screens shall conform to the alphanumeric resistance limits of Table 15.

26.9 Miniature Controls:

26.9.1 Use—Miniature controls may be used only when severe space limitations exist. Miniature controls shall not be used when available space is adequate for standard-sized controls or when heavy gloves or mittens will be worn.

26.9.2 Dimensions, Resistance, Displacement, and Separation—When design constraints dictate the use of miniature controls, the dimensions and separation of the controls shall be the maximum permitted by the available space up to the maxima prescribed herein for standard-sized controls. Resistance and displacement of miniature controls shall conform to the criteria specified for the standard size of that type of control.

| TABLE 18 Limiting Dimensions for Free-Moving X-Y Controller |
|-----------------------------|-----------------------------|
| Dimension                   | Minimum | Maximum |
|                             | mm | (in.) | mm | (in.) |
| Width (spanned by thumb to  | 40 (1.6) | 70 (2.8) |
| finger grasp)               |       |       |
| Length                      | 70 (2.8) | 120 (4.7) |
| Thickness                   | 25 (1.0) | 40 (1.6) |
26.9.3 Other Requirements—Other design considerations (labeling, orientation, and so forth) shall conform to the requirements specified for the standard size of the control.

27. General Requirements for Labeling

27.1 Application—Labels shall be provided whenever it is necessary for personnel to identify equipment, follow procedures, or avoid hazards, except where it is obvious to the observer what an item is and how it may be used.

27.2 Characteristics—Label characteristics shall be consistent with such factors as:

27.2.1 Accuracy of identification required.
27.2.2 Time available for recognition or other responses.
27.2.3 Distance at which the labels must be read.
27.2.4 Illuminant level and color.
27.2.5 Criticality of the function labeled.
27.2.6 Consistency of label design within and between systems.

27.3 Types:
27.3.1 Label—The term label, when used alone, shall mean any type of plate, sign, placard, inscription, legend, marking, or combination of these, that is used for purposes of identification, or to impart information or instructions to the reader. This term is used generically herein to describe all the specific types of labels described below.

27.3.2 Identification Label—An identification label is a specific type of label used for identification purposes only. Identification labels are used to identify such things as spaces, locations, equipment, systems, controls and displays, classifications (for example, damage control and control), and so forth.

27.3.3 Hazard Label—The term hazard plate is used to describe a specific category of labels that are used to identify and provide information about existing or potential situations that may be hazardous to ship personnel or equipment. There are only two required types of hazard labels: the danger label, and the caution label. For U.S. Navy ships, a third type is required, warning labels. The difference between a danger label, warning label, and a caution label is the degree of seriousness of the potential hazard, as defined below.

27.3.3.1 Danger Label—A danger label is a type of hazard label and is used to identify and provide information about a situation in which an action or omission of one on the part of the crew member could result in serious injury or death, serious damage to vital equipment, or a major reduction in the ship’s capability to perform its mission.

27.3.3.2 Warning Label—A warning label is used to indicate a location, equipment, or system in which a potential hazard exists, capable of producing injury or death to personnel, if approved procedures are not followed.

27.3.3.3 Caution Label—A caution label is a type of hazard label and is used to identify and provide information about a situation in which an action or omission of one on the part of the crew member could result in a minor injury, minor damage to equipment, or a minor reduction in the ship’s capability to perform its mission.

27.3.4 Instruction Label—An instruction label is a specific type of label used to present step-by-step instructions for accomplishing a specific task (operation or maintenance related) and to provide hazard and safety information related to performing the task.

27.3.5 Information Label—An information label is a specific type of label used to present nonprocedural, information of a general nature, related to health, first aid, sanitation, rules, housekeeping, general conduct, and so forth.

28. Label Content

28.1 Abbreviations:
28.1.1 Criteria for Use—Abbreviating a word or word group shall be used only if one of two conditions exists:
28.1.1.1 There is insufficient space available at the location where the label is to be affixed for the design of a label that would allow the entire inscription to be spelled out.
28.1.1.2 The abbreviation is more commonly known and understood by the user population than the spelled out word or word group.

28.1.2 Criteria for Development—If the need for an abbreviation has been justified, and a standard abbreviation does not exist in MIL-STD-12, nor does a standard abbreviation exist that is commonly understood and recognized by the intended user population, then, the following rules shall be applied to develop the abbreviation.

28.1.3 Case—Capital letters shall be used for abbreviations.
28.1.4 Single Words—When abbreviating single words:
28.1.4.1 Determine the number of characters required in the abbreviated term.
28.1.4.2 The same abbreviation shall be used for all tenses and for both singular and plural forms of a word. Remove

### TABLE 19 Arm Strength

<table>
<thead>
<tr>
<th>Elbow Flexion rad (°)</th>
<th>Pull</th>
<th>Push</th>
<th>Up</th>
<th>Down</th>
<th>In</th>
<th>Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>R</td>
<td>L</td>
<td>R</td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>3.14 (180)</td>
<td>222 (50)</td>
<td>231 (52)</td>
<td>187 (42)</td>
<td>222 (50)</td>
<td>40 (9)</td>
<td>62 (14)</td>
</tr>
<tr>
<td>2.18 (150)</td>
<td>187 (42)</td>
<td>259 (58)</td>
<td>133 (30)</td>
<td>187 (42)</td>
<td>67 (15)</td>
<td>80 (18)</td>
</tr>
<tr>
<td>2.09 (120)</td>
<td>151 (34)</td>
<td>197 (42)</td>
<td>116 (26)</td>
<td>160 (36)</td>
<td>76 (17)</td>
<td>107 (24)</td>
</tr>
<tr>
<td>1.57 (90)</td>
<td>142 (32)</td>
<td>165 (37)</td>
<td>98 (22)</td>
<td>160 (36)</td>
<td>76 (17)</td>
<td>89 (20)</td>
</tr>
<tr>
<td>1.05 (60)</td>
<td>116 (26)</td>
<td>107 (24)</td>
<td>98 (22)</td>
<td>151 (34)</td>
<td>67 (15)</td>
<td>89 (20)</td>
</tr>
</tbody>
</table>

### TABLE 20 Hand and Thumb-Finger Strength

<table>
<thead>
<tr>
<th>N (lb) (Fifth Percentile Male Data)</th>
<th>Hand Grip</th>
<th>Thumb-Finger Grip (Palmer)</th>
<th>Thumb-Finger Grips (Tips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>R</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>Momentary Hold</td>
<td>249.1 (56)</td>
<td>222.4 (50)</td>
<td>57.8 (13)</td>
</tr>
<tr>
<td>Sustained Hold</td>
<td>146.7 (33)</td>
<td>155.7 (35)</td>
<td>35.6 (8)</td>
</tr>
</tbody>
</table>
suffixes such as -ed, -es, -er, and -ing from the word to be abbreviated. (Make sure they are suffixes, as in “waxing,” and not an integral part of the word, as in “spring.”)

28.1.4.3 Choose the first letter and last consonant of the word to be abbreviated as the first and last letter of the abbreviation. For example, Multiplexor would be M–R.

28.1.4.4 Fill the remaining spaces with the consonants in the order in which they appear in the word. Avoid the use of a double consonants in the abbreviation. For example, a five-character abbreviation for Multiplexor would be MLTPR, a four-character abbreviation would be MLTR, and three-character abbreviation would be MLR.

28.1.4.5 If there are insufficient consonants, use the first vowel in the order in which it appears in the word. For example, an eight-character abbreviation for Multiplexor would be MULTPLXR.

28.1.5 Two-Word Groups—When abbreviating two-word groups:

28.1.5.1 Determine the number of characters required in the abbreviated term.

28.1.5.2 Take half of the characters from the first word and the other half from the second word, using the above abbreviation methodology for single words. If an odd number of total characters is needed, take the odd character from the longer word. For example, a five-character abbreviation for Area Multiplexor would be AR MLR.

28.1.6 Three or More Word Groups—When abbreviating groups of three or more words, form an acronym by using the first letter of each word. For example, Aqueous Film Forming Foam would be abbreviated AFFF.

28.1.7 Standardization—Abbreviations shall be standardized and used consistently on the labels. All abbreviations which are not found in MIL-STD-12 shall be approved by the procuring activity before being used.

28.1.8 Punctuation—Periods or other punctuation shall not be used after abbreviations.

28.2 Brevity—Labels shall be as concise as possible without distorting the intended meaning or information and shall not be ambiguous. The amount of information provided shall be only that required to convey a clear message to the intended user; however, brevity shall not be stressed if the results will be unfamiliar to the user. Excessive detail, redundant words, phrases, and information shall be avoided.

28.3 Familiarity—Words and abbreviations shall be chosen on the basis of familiarity by the intended user population. For particular users (for example, maintenance technicians), common technical terms may be used even though they may be unfamiliar to crew members who are not expected to be part of the user population.

28.4 Irrelevant Information—Trade names, company logos, or other information not directly required by the user shall not appear on any labels, or be the subject of a label.

28.5 Symbols:

28.5.1 Dependent Symbols—Symbols that alone do not impart any specific information to the user (for example, %, +, −), but require the existence of supporting data to provide meaningful information (for example, 10 %, +5 psi, 3 lbs).

28.5.2 Independent Symbols—Symbols that alone provide information to the user and normally are associated with hazard or emergency situations. Examples of independent symbols suitable for shipboard use are shown in Fig. 51.

28.5.3 Use—Dependent symbols shall be used only when they have an accepted meaning to all intended users. Independent symbols may be integrated with any label that addresses the subject of the symbol (for example, a hazard label that identifies a potential shock hazard may contain the lightning bolt symbol). An independent symbol shall not be used alone to identify a hazardous situation; it shall always be accompanied by appropriate text as specified herein. An independent symbol may be used alone for nonhazardous identification purposes (for example, the first aid cross symbol may be used alone to identify a first aid kit).

28.6 Format:

28.6.1 Consistent—All labels of the same type shall be consistent in format and presentation of information.

28.6.2 Heading—Headings and subheadings shall be used to identify groups of related information. Headings and subheadings shall be of larger character size than the text of the label, with the major heading or label title the largest and subheadings of subsequently smaller size.

28.6.3 Integrated Safety and Hazard—Safety and hazard information that is integrated with other information (such as instructions) on labels other than hazard label shall be designed such that the safety and hazard information is clearly and distinctly different, visually, from the other information and is easily identified by the user.

28.7 References—References directing the user to other documents or sources of information shall not be made in a label if the referenced material is required to complete a task, recognize or avoid a hazardous situation, or clearly or completely understand the message of the label. References to other documents or sources of information may be used only to direct the user to supplemental information.

28.8 Character/Background Color:

28.8.1 Background and Character Color—Label background color shall contrast with the color of the surface to which it will be affixed. Any special background color shall be approved by the procuring activity before its use.

28.8.2 Other Labels—Where the ambient illuminance will be above 0.9 ft-c (10 lux), identification labels, instruction labels, information labels, and graphic labels (all labels other than hazard labels) shall be provided with black characters on a light background. Where dark adaptation lighting (low level
white or red) is required, the displayed letters or numerals shall be visible without interfering with night vision requirements. Where possible, markings shall be white on a dark background.

28.9 Reflection—The use of glossy or highly reflective metallic materials for either the lettering or background shall be avoided.

28.10 Characters and Numerals:

28.10.1 Style—Characters shall be a simple block-type font, such as alternate gothic #2, news or trade gothic, or futura or spartan medium. All numerals shall be arabic.

28.10.2 Capital and Lowercase—All capital letters shall be used for identification labels, headings and subheadings, signal words such as danger, caution, attention, notice, legends, and short message labels. Capital and lowercase letters shall be used for extended sentence messages in which it is necessary to use punctuation.

28.10.3 Letter Width—The width of letters shall be ⅔ of the height, except for “M” and “W,” which shall be ⅔ of the height, and “I” which shall be one stroke wide.

28.10.4 Numerical Width—The width of numerals shall preferably be ⅔ of the height, except for the “4,” which shall be one stroke width wider, and the “1” which shall be one stroke wide.

28.10.5 Wide Characters—Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio may be increased to 1:1.

28.10.6 Stroke Width Normal—For black characters on a white (or light) background, the stroke width shall be ⅓ to ⅔ of the height.

28.10.7 Stroke, Width, Dark Adaptation—Where the dark adaptation is required or legibility at night is a critical factor, and white characters are specified on a black background, the stroke width of the characters shall be from ¼ to ⅓ of the height (narrower than specified for normal daytime vision). The stroke width shall be the same for all letters and numerals of equal height.

28.10.8 Stroke Width, Transilluminate Characters—For transilluminate characters, the stroke width shall be ¼ of the height.

28.10.9 Character Spacing—The minimum space between characters shall be one stroke width.

28.10.10 Word Spacing—Separation between words shall be the width of three characters (±½ width). The minimum space between words shall be the width of one character.

28.10.11 Line Spacing—The minimum space between lines shall be ¼-character height, but in no case shall the separation between the tallest character on a lower line be less than one stroke width from a character above that projects below the line.

28.10.12 Character Height and Viewing Distance—For general and panel design, with the luminance normally above 3.5 cd/m² (1 ft-L), for labels of all types, minimum character height shall conform to the following values for various expected viewing distances:

<table>
<thead>
<tr>
<th>Viewing distance mm (in.)</th>
<th>Minimum height mm (in.)</th>
<th>Minimum height pt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 500 (19.7)</td>
<td>2.3 (0.09)</td>
<td>[6]</td>
</tr>
<tr>
<td>500–1000 (19.7–39.4)</td>
<td>4.7 (0.18)</td>
<td>[12]</td>
</tr>
<tr>
<td>1000–2000 (39.4–78.7)</td>
<td>9.4 (0.37)</td>
<td>[26]</td>
</tr>
</tbody>
</table>

28.10.13 Letter and Numbers to Avoid—Avoid using the number “1” in combination with letter “L” or “I” and the number zero together with the letters “O” or “Q.”

28.11 Graphics:

28.11.1 Lines—The minimum stroke width for lines shall be equal to the minimum stroke width for characters.

28.11.2 Location—Label location throughout the ship shall be as consistent and uniform from space to space, system to system, as possible.

28.11.3 Label Groups—Placement of several (more than three) labels in a group shall be avoided. However, if more than one label is required to be mounted in the same location, the labels shall be grouped by label type and organized as follows:

28.11.3.1 Hazard labels shall be grouped together and be mounted in the most prominent location.

28.11.3.2 Instruction labels shall be mounted in the next most prominent location.

28.11.3.3 Information labels and graphic plates shall be mounted in the next most prominent location.

28.11.3.4 Graphic labels that are referenced by other types of labels shall be mounted adjacent to the referencing label.

28.11.3.5 Identification labels shall be mounted to ensure maximum visibility and shall be placed on or immediately adjacent to the items they identify. Mounting labels on bulkheads or other ship structures for identification of valves, machinery, or other equipment shall be avoided.

28.11.4 Preinstalled Labels—Items that have labels installed before the item is located in the ship shall be placed so the labels are visible and legible after the item is in place.

28.11.5 Visibility and Legibility—Labels shall be designed for easy and accurate reading based on the anticipated reader’s viewpoint and reading distance, ship vibration, ship motion, and ambient illumination levels. Labels shall not be covered or obscured by other equipment.

28.11.6 Label Surface—Labels shall be placed on flat surfaces. If a label must be located on a curved surface, it must be completely visible to the observer. If the curvature is such that the characters become too small to read, another mode of labeling shall be used (for example, on attached tag).

28.11.7 Label Life—Labels shall be constructed and mounted so as to remain legible for the lifetime of the label.

29. Specific Requirements by Label Type

29.1 Identification Label—There are no specific requirements for the use and format of identification label. Identification labels shall comply with all requirements for labels in general, as specified herein.

29.2 Hazard Labels:

29.2.1 Criteria for Use—Depending on the severity of the potential hazard, an appropriate danger or caution label shall be provided wherever it is necessary to minimize the possibility of injury to personnel, damage to equipment or systems or where special precautions must be exercised. Examples of the need for danger or caution labels include the following:

29.2.1.1 Fixed physical obstructions,

29.2.1.2 Moving or rotating equipment,
29.2.1.3 Equipment contact hazards (high voltage, high or low temperature, and so forth),
29.2.1.4 Radiation hazards (electromagnetic or nuclear),
29.2.1.5 Laser beam,
29.2.1.6 Toxic fumes exposure or toxic chemical contact,
29.2.1.7 Flash or high intensity light (welders, strobe lights), and

29.2.1.8 Requirements for safety equipment or clothing.
29.2.2 Danger/Warning/Caution Selection Criteria—
Selection of a danger, warning, or caution label shall be based on the descriptions given in Section 27.

29.2.3 Format:
29.2.3.1 General—Hazard labels shall be designed with an upper and lower component. The upper component shall contain the appropriate signal word, (DANGER, WARNING or CAUTION) and the lower component shall contain the necessary hazard inscription, as specified herein.

29.2.3.2 Signal Word—Danger labels shall contain only the signal word DANGER in the upper part of the label. Warning or caution labels shall contain only the signal word WARNING or CAUTION in the upper part of the label.

29.2.4 Inscription—All hazard labels shall contain, in the lower component, the following pieces of information presented in the order in which they are described below;
29.2.4.1 A brief statement of the hazard. If more than a single hazard is being identified, they shall be provided in a list rather than in paragraph format.
29.2.4.2 A brief statement instructing the reader how to avoid the stated hazard(s). If more than a single instruction is required, they shall be provided in step-by-step format rather than in paragraph format.

29.2.4.3 A brief statement of the potential consequences if the instructions for avoiding the hazard are not followed. If more than a single consequence is likely, they shall be provided in a list rather than paragraph format.

29.2.5 Lettering—The signal word shall be at least 50 % larger than the inscription text.

29.3 Character/Background Color:
29.3.1 General—Hazard labels shall be designed with an upper and lower component. The upper component shall contain the appropriate signal word (DANGER, WARNING, or CAUTION), and the lower component shall contain the necessary hazard inscription. See ANSI Z535.2 for label formats.

29.3.1.1 The signal word DANGER shall be in white letters on a red oval background with a white border on a black rectangular field. The inscription text shall be black characters on a white background.

29.3.1.2 The signal word DANGER and the text inscription shall be in white characters on a red background.

29.3.2 Warning or Caution Labels—Warning or caution labels shall comply with one of the two following character/background color schemes:

29.3.2.1 The signal word WARNING or CAUTION shall be yellow characters on a black rectangular background. The inscription text shall be black characters on a yellow background.

29.3.2.2 The signal word WARNING shall be black characters within a yellow truncated diamond on a black rectangular background. The inscription shall be black letters on a yellow background.

29.3.3 Caution Labels—The signal word CAUTION shall be yellow characters on a black rectangular background. The inscription shall be black letters on a yellow background.

29.4 Instruction Labels—An instruction label shall only be provided when:
29.4.1 It is likely that an item of equipment or system will be operated or maintained by personnel not trained for the task and the item of equipment or system is critical to the survivability or mission of the ship.

29.4.2 An item of equipment is authorized for use by all ship personnel and little or no training in its operation is provided.

29.4.3 The operation or maintenance of an item of equipment or system is lengthy and complex and it is likely that the task will have to be performed without the benefit of standard operating or maintenance procedure manuals or documents.

29.4.4 Format:
29.4.4.1 Title—All instruction labels shall be titled at the top of the label. The title shall identify the instructions as operating or maintenance, or both, and shall identify the equipment or system being addressed.

29.4.4.2 Hazard and Safety—Hazard and safety information that pertains to the task in general shall be provided on the label preceding the instructions. This information shall be labeled with a heading that identifies it as general hazard and safety information. Each statement identifying a potential hazard shall begin with the appropriate signal word DANGER, WARNING, or CAUTION.

29.4.4.3 Inscription—Instructions for completing the task shall be provided in numbered step-by-step format. Each step shall be stated as briefly and generically as possible. The instructions shall avoid the use of specific equipment model names or numbers or other aspects of the equipment or system that may change at some future time. Hazard and safety information that pertains to a particular step or steps in the procedure shall be provided immediately preceding the step or steps in the instructions. Each statement identifying a potential hazard shall begin with the appropriate signal word DANGER, WARNING, or CAUTION. Instructions shall be provided on a separate label from diagrams, schematics, charts, or other types of graphic labels, which may be referenced in the instructions. If operating instructions and maintenance instructions are provided on the same label, the operating instructions shall appear first, and the two groups of information shall be labeled with appropriate headings.

29.4.4.4 Lettering—The label title shall be at least 50 % larger than headings. Headings shall be at least 25 % larger than the inscription text.

29.5 Information Labels:
29.5.1 Criteria for Use—An information label shall only be provided when the information presented the reader will significantly contribute to the general safety, health, or readiness of the ship. Information labels shall not be used in place...
of hazard labels to identify potential hazards or in place of instruction labels to identify procedures for performing a task.

29.5.2 Format:
29.5.2.1 General—Information labels shall be designed with an upper and lower component. The upper component shall contain an appropriate signal word, and the lower portion shall contain the necessary information inscription, as specified below.

29.5.2.2 Signal Word—Information labels shall contain the signal word ATTENTION in the upper panel.

29.5.2.3 Inscription—The inscription may be presented in paragraph format; however, if the information or a portion of it is a list, that information shall be presented in a list format. Excessive amounts of detail shall be avoided. Headings shall be used, as appropriate, to organize and identify related information.

29.5.2.4 Lettering—The signal word shall be at least 50% larger than headings. Headings shall be at least 25% larger than the inscription text.

29.6 Graphic Labels:
29.6.1 Criteria for Use—A graphic label, which may take the form of a diagram, schematic, chart, and so forth, should be used only when such information is absolutely necessary or required.

29.6.2 Format:
29.6.2.1 Title—All graphic labels shall be titled at the top of the label. The title shall identify the equipment, system, or information being presented. If more than one schematic or diagram is presented on a single label, each shall be labeled with a heading.

29.6.2.2 Schematics and Diagrams—All graphic symbols and special nomenclature used on a graphic label shall be defined in a legend. Descriptive text shall be as brief as possible and shall not obscure or congest the diagram or schematic. Information shall be provided on the label that indicates location and orientation of the equipment or system in the ship, as appropriate.

29.6.2.3 Charts—All charts of the same type, or used for the same purpose, such as lubrication charts, shall be of the same format, including the use of the same headings, units of measure, and organization and presentation of information.

29.6.2.4 Lettering—The label title shall be at least 50% larger than headings. Headings shall be at least 25% larger than the smallest text.

29.7 Control and Displays Labels:
29.7.1 General—Controls and displays shall be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the element.

29.7.2 Simplicity—Control and display labels shall convey verbal meaning in the most direct manner, by using simple words and phrases.

29.7.3 Functional Labeling—Each control and display shall be labeled according to function, and the following criteria shall apply:

29.7.3.1 Similar names for different controls and displays shall be avoided.

29.7.3.2 Instruments shall be labeled in terms of what is being measured or controlled, taking into account the user and purpose.

29.7.3.3 Control labeling shall indicate the functional result or control movement (for example, increase, ON, OFF) and may include calibration data where applicable. Such information shall be visible during normal operation of the control.

29.7.3.4 When controls and displays must be used together (in certain adjustment tasks), appropriate labels shall indicate their functional relationship. The selection and use of terminology shall be consistent.

29.7.3.5 The units of measurement (volts, psi, inches, and so forth) shall be labeled on the panel.

29.7.4 Location—Label location throughout a system and within panel groupings shall be uniform. The following criteria shall apply to the location of control and display labels:

29.7.4.1 Ease of control operation shall be given priority over visibility of control position labels.

29.7.4.2 Labels shall normally be placed above the controls and displays they describe. When the panel is above eye level, labels may be located below if label visibility will be enhanced. Controls shall not obscure labels.

29.7.4.3 Labels shall be used to identify functionally grouped controls and displays. The labels shall be located above the functional groups they identify. When a line is used to enclose a function group and define its boundaries, the label shall be centered at the top of the group either in a break in the line or just below the line. When colored pads are used, the label shall be centered at the top within the pad area.

29.7.5 Character Size Versus Luminance—The height of letters and numerals shall be determined by the required reading distance and luminance. With a 28 in viewing distance, the height of numerals and letters shall be within the range of values, specified in points, provided in Table 21 for “low” and “high” control-display luminance conditions.

29.7.6 Size Graduation—Labels shall be graduated in size beginning with the smallest (control position labels) being determined by viewing conditions. Each increase in size shall be approximately 25% larger. Guidelines for control-display label size gradations are shown in Fig. 52.

29.8 Units, Assemblies, Subassemblies, and Parts:

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**TABLE 21** Character Size Versus Luminance

<table>
<thead>
<tr>
<th>Markings</th>
<th>Character Heighta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Light (Below 1 ft-L), mm (in.) [pt]</td>
</tr>
<tr>
<td>For critical markings, with positions variable (numerals on counters, settable or moving scales, and so forth)</td>
<td>5.5–8.6 (0.21–0.33)</td>
</tr>
<tr>
<td>For critical markings, with position fixed (numerals on fixed scales, controls, switch markings, emergency instructions, and so forth)</td>
<td>4.7–8.6 (0.18–0.33)</td>
</tr>
<tr>
<td>For noncritical markings (identification labels, routine instructions, markings required only for familiarization)</td>
<td>1.6–5.5 (0.07–0.21)</td>
</tr>
</tbody>
</table>

aValues assume a 711-mm (28-in.) viewing distance. For Distance D, other than 28 in., multiply the character height by D/28 and round to the next higher point.
29.8.1 General—Each unit, assembly, subassembly, and part shall be labeled with a clearly visible, legible, and meaningful name, number, code, mark, or symbol as applicable.

29.8.2 Simplicity—Equipment shall be labeled with terms descriptive of the test or measurement applicable to their test points (for example, demodulator rather than crystal detector and power amplifier rather than bootstrap amplifier).
29.8.3 Location—The gross identifying label on a unit, assembly, or major subassembly shall be located:
29.8.3.1Externally in such a position it is not obscured by adjacent items.
29.8.3.2 On the flattest, most uncluttered surface available.
29.8.3.3 On a main chassis of the equipment.
29.8.3.4 In a way to minimize wear or obscurement by grease, grime, or dirt.
29.8.3.5 In a way to preclude accidental removal, obstruction, or handling damage.
29.9 Prototype and Production Equipment Labels—Labels for both prototype and production equipment shall meet the criteria specified herein. Labels for production equipment shall meet the criteria specified for the duration of equipment use. Since frequent design changes may be anticipated in prototype equipment, labels for such equipment shall be simply and easily affixed, altered, and removed.

29.10 Installation:
29.10.1 Orientation—Labels shall be horizontal and read from left to right. Where space is limited and the label is not critical for personnel or equipment safety, a vertical label may be used that shall read from top to bottom. Labels shall not be placed on controls that turn (except value handwheels) which could place the label in an upside down position.

30. Anthropometry

30.1 General—The design of any system, individual piece of equipment, or total vessel is most efficient and cost effective if it is laid out from the beginning, around the human. One important aspect of designing to accommodate the human is to ensure that the design is compatible with the physical dimensions of the human body. Consequently, design limits shall be based on a range from the fifth to the ninety-fifth percentile for critical body dimensions. If females are expected users, then the fifth percentile dimensions used shall be those for women. If males only will be the users, then the lower design limit shall be fifth percentile dimensions for men. The upper design limit is always for the ninety-fifth percentile male. For any body dimension, the fifth percentile value indicates that 5% of the population will be equal to or smaller than that value, and 95% will be larger; conversely, the ninety-fifth percentile values indicate that 95% of the population will be equal to or smaller than that value and 5% will be larger. Therefore, use of a design range from the fifth to the ninety-fifth percentile values will theoretically provide coverage for 90% of the user population for that dimension. The limited anthropometric data presented in this section is intended to provide general design guidance. Use of these data shall take the following into consideration:

30.1.1 The nature, frequency, safety, and difficulty of the related tasks to be performed by the operator or wearer of the equipment.
30.1.2 The position of the body during performance of these tasks.
30.1.3 Mobility or flexibility requirements imposed by these tasks.
30.1.4 Increments in the design-critical dimensions imposed by the need to compensate for obstacles, projections, and so forth.

30.1.5 Increments in the design-critical dimensions imposed by protective clothing or equipment, packages, lines, padding, and so forth.

30.2 Anthropometric Data—The anthropometric data presented in Figs. 53-58 and Table 22 represent various body measurements, that is, anthropometric data. The open numbers are for the nude body, and are given for the fifth and ninety-fifth percentile male and female in both inches and centimetres. Fig. 59 presents anthropometric data for several dynamic body positions often involved in work activities. Figs. 60-62 provide dimensions for head and hand protectors frequently worn by personnel on a ship.

30.3 Use of Data:

30.3.1 Data Limitations—Because some of the anthropometric data presented here represent only nude body measurements, suitable allowances shall be made for light or heavy clothing, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items, when using these data for design criteria.

30.3.2 Clearance Dimensions—Clearance dimensions (for example, for passageways and access areas) that must accommodate or allow passage of the body or parts of the body shall be based upon the ninety-fifth percentile values for applicable body dimensions.

30.3.3 Limiting Dimensions—Limiting dimensions (reaching distance, control movement, displays, test points, handrails, and so forth) that restrict or are limited by extensions of the body shall be based upon the fifth percentile values for applicable body dimensions.

30.3.4 Adjustment Dimensions—Seats, restraint systems, safety harnesses, belts, controls, or any equipment that must be adjusted for the comfort or performance of the individual user shall be adjustable over the range of the fifth to ninety-fifth percentile values for the applicable body member(s).

30.3.5 Clothing and Personal Equipment—Clothing and personal equipment (including protective or specialized equipment worn or carried by the individual) shall be designed and sized to accommodate at least the fifth through the ninety-fifth percentile values of body dimensions. Pertinent dimensions of essential or critical equipment (for example, aviators’ helmets) shall be based on the first and ninety-ninth percentile values. Where two or more dimensions are used simultaneously as design parameters, appropriate multivariate data and techniques shall be used. (See appendix for representative references.)

30.4 Special Populations—Where equipment will be used, inclusively or exclusively, by selected or specialized segments of the user population or population ranges other than the fifth to ninety-fifth percentiles, appropriate available anthropometric data on these specialized populations shall be used for design and sizing criteria. Where equipment is intended for use by foreign personnel, appropriate anthropometric data on such populations shall be used for design and sizing criteria.

30.5 Range of Human Motion—The range of body movement for the arms, legs, and head are shown in Fig. 63 and Table 23. These values are based on the nude body and would have to be reduced for the clothed personnel.
<table>
<thead>
<tr>
<th>Standing Body Dimensions</th>
<th>5th Percentile, cm (in.)</th>
<th>95th Percentile, cm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 STATURE</strong></td>
<td>Male</td>
<td>Arctic A</td>
</tr>
<tr>
<td></td>
<td>164.5</td>
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<td></td>
<td>(64.8)</td>
<td>(68.2)</td>
</tr>
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<td>152.8</td>
<td>157.7</td>
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<tr>
<td></td>
<td>(60.2)</td>
<td>(62.1)</td>
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<tr>
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<td>134.2</td>
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<tr>
<td></td>
<td>(52.6)</td>
<td>(54.5)</td>
</tr>
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<td><strong>4 CHEST (NIPPLE) HEIGHT</strong></td>
<td>118.6</td>
<td>108.9</td>
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<tr>
<td></td>
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<td>(42.9)</td>
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<td></td>
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<td>(47.2)</td>
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<td>99.1</td>
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<td></td>
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<td>(7.1)</td>
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<td>(36.7)</td>
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### TABLE 22  Continued

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<th>95th Percentile, cm (in.)</th>
<th>5th Percentile, cm (in.)</th>
<th>95th Percentile, cm (in.)</th>
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<tbody>
<tr>
<td>Male</td>
<td>Arctic^A 61.8 kg (135.8 lbs)</td>
<td>Female 46.4 kg (102.3 lbs)</td>
<td>Male Arctic^A 98.1 kg (216.3 lbs)</td>
<td>Female 77.0 kg (169.8 lbs)</td>
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<td>32 CHEST DEPTH</td>
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<td>33 BUTTOCK DEPTH</td>
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<td></td>
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<tr>
<td>34 CHEST BREADTH</td>
<td></td>
<td></td>
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</tr>
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<td>35 HIP BREADTH, STANDING</td>
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<td>36 SHOULDER (BIDELTOID) BREADTH</td>
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<td>37 FOREARM-FOREARM BREADTH</td>
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<td>38 HIP BREADTH, SITTING</td>
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<tr>
<td>39 NOT USED</td>
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<td>40 NECK CIRCUMFERENCE</td>
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<td>41 CHEST (BUST) CIRCUMFERENCE</td>
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<td>42A WAIST CIRCUMFERENCE (OMPHALION)</td>
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<td>42B WAIST CIRCUMFERENCE, (NATURAL INDENTATION)</td>
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<tr>
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<td>47 ARM SCYE CIRCUMFERENCE</td>
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<td>48 BICEPS CIRCUMFERENCE, FLEXED</td>
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<td>50 FOREARM CIRCUMFERENCE, FLEXED</td>
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<td>55B WAIST (NATURAL INDENTATION) BACK LENGTH</td>
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<td>56A WAIST (OMPHALION) FRONT LENGTH</td>
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<td>56A WAIST (NATURAL INDENTATION) FRONT LENGTH</td>
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<tr>
<td>57 HAND LENGTH</td>
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<td></td>
</tr>
<tr>
<td>58 PALM LENGTH</td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>60 HAND CIRCUMFERENCE</td>
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**Hand and Foot Dimensions**

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</thead>
<tbody>
<tr>
<td>57 HAND LENGTH</td>
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<td>21.1 (8.3)</td>
</tr>
<tr>
<td>58 PALM LENGTH</td>
<td>9.6 (3.8)</td>
<td>10.4 (4.1)</td>
</tr>
<tr>
<td>59 HAND BREADTH</td>
<td>8.2 (3.2)</td>
<td>12.7 (5.0)</td>
</tr>
<tr>
<td>60 HAND CIRCUMFERENCE</td>
<td>19.9 (7.8)</td>
<td>16.8 (6.6)</td>
</tr>
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### 31. Workspace Design Requirements

31.1 General—The following criteria apply to workspace design requirements.

<table>
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<tr>
<th>5th Percentile, cm (in.)</th>
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<tbody>
<tr>
<td>Male</td>
<td>Arctic^A</td>
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<tr>
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<td>61.8 kg (135.8 lbs)</td>
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<tr>
<td>62 FOOD LENGTH</td>
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<td>63 INSTEP LENGTH</td>
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**TABLE 22 Continued**

**Head and Face Dimensions**

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<td>(8.3)</td>
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<td>(5.7)</td>
<td>(5.6)</td>
<td></td>
</tr>
<tr>
<td>78 HEAD HEIGHT (TRAGION TO TOP OF HEAD)</td>
<td>7.6</td>
<td>7.7</td>
<td>10.8</td>
<td>10.0</td>
</tr>
<tr>
<td>(3.3)</td>
<td>(3.0)</td>
<td>(4.3)</td>
<td>(3.9)</td>
<td></td>
</tr>
<tr>
<td>79 GLABELLA TO TOP OF HEAD</td>
<td>13.8</td>
<td>12.8</td>
<td>16.6</td>
<td>16.8</td>
</tr>
<tr>
<td>(5.4)</td>
<td>(5.0)</td>
<td>(6.5)</td>
<td>(6.6)</td>
<td></td>
</tr>
<tr>
<td>80 PRONASALE TO TOP OF HEAD</td>
<td>10.7</td>
<td>9.6</td>
<td>13.3</td>
<td>12.4</td>
</tr>
<tr>
<td>(4.2)</td>
<td>(3.8)</td>
<td>(5.2)</td>
<td>(4.9)</td>
<td></td>
</tr>
<tr>
<td>81 FACE LENGTH (MENTON-SELLION)</td>
<td>13.1</td>
<td>11.9</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>(5.2)</td>
<td>(4.7)</td>
<td>(5.9)</td>
<td>(5.5)</td>
<td></td>
</tr>
<tr>
<td>82 FACE (BIZYGOMATIC) BREADTH</td>
<td>11.3</td>
<td>11.1</td>
<td>13.1</td>
<td>12.9</td>
</tr>
<tr>
<td>(4.4)</td>
<td>(4.4)</td>
<td>(5.2)</td>
<td>(5.1)</td>
<td></td>
</tr>
<tr>
<td>83 BILOCULAR BREADTH</td>
<td>5.4</td>
<td>5.1</td>
<td>7.1</td>
<td>6.9</td>
</tr>
<tr>
<td>(2.1)</td>
<td>(2.0)</td>
<td>(2.8)</td>
<td>(2.7)</td>
<td></td>
</tr>
<tr>
<td>84 INTERPUPILLARY BREADTH</td>
<td>4.4</td>
<td>3.7</td>
<td>6.3</td>
<td>6.2</td>
</tr>
<tr>
<td>(1.7)</td>
<td>(1.5)</td>
<td>(2.5)</td>
<td>(2.4)</td>
<td></td>
</tr>
<tr>
<td>85 NOT USED</td>
<td>2.5</td>
<td>2.5</td>
<td>3.6</td>
<td>3.3</td>
</tr>
<tr>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(1.4)</td>
<td>(1.3)</td>
<td></td>
</tr>
<tr>
<td>86 NOT USED</td>
<td>3.2</td>
<td>2.4</td>
<td>4.2</td>
<td>3.9</td>
</tr>
<tr>
<td>(1.3)</td>
<td>(0.9)</td>
<td>(1.7)</td>
<td>(1.5)</td>
<td></td>
</tr>
<tr>
<td>88 NOT USED</td>
<td>1.7</td>
<td>1.7</td>
<td>3.0</td>
<td>2.7</td>
</tr>
<tr>
<td>(0.7)</td>
<td>(0.7)</td>
<td>(1.2)</td>
<td>(1.1)</td>
<td></td>
</tr>
</tbody>
</table>

^Numbers are for males only dressed in arctic clothing.
31.1.1 Kick Space—All cabinets, consoles, and work surfaces that require an operator to stand or sit close to their front surfaces shall contain a kick space at the base at least 100 mm (4 in.) deep and 100 mm (4 in.) high to allow for protective or specialized apparel.

31.1.2 Handles—Handles on cabinets and consoles shall be recessed whenever practicable to eliminate projections on the surface. If handles cannot be recessed, they shall be designed such that they shall neither injure personnel nor entangle clothing or equipment.

31.1.3 Work Space—Work space shall be provided to perform all operational and maintenance tasks by the fifth to ninety-fifth percentile person wearing the appropriate clothing and using the required tools. In establishing the work space, consideration shall be given to the number of personnel required to perform the work and the body positions required to do the work. Dimensions for typical work positions are shown in Fig. 64 and Table 24.

31.1.3.1 Depth of Work Area—Clearance from the front of the rack to the nearest facing surface or obstacle shall not be less than 1.07 m (42 in.). The minimum space between rows of cabinets shall be 200 mm (8 in.) greater than the depth of the deepest drawer (equipment).

31.1.3.2 Lateral Work Space—The minimum lateral workspace for racks having drawers or removable equipment shall be as follows (measured from the drawers or equipment in the extended position):

(a) For racks having drawers or removable items weighing less than 20 kg (44 lbs): 460 mm (18 in.) on one side and 100 mm (4 in.) on the other.

(b) For racks having drawers or removable items weighing over 20 kg (44 lbs): 460 mm (18 in.) on each side.
31.1.3.3 **Space Between Rows of Cabinets**—The minimum space between rows of cabinets shall be 200 mm (8 in.) greater than the depth of the deepest drawer or cabinet.

31.1.4 **Storage Space**—Adequate and suitable space shall be provided on consoles or immediate work space for the storage of manuals, worksheets, and other materials that are required for use by the operational or maintenance personnel.

31.2 **Standing Operations**:

31.2.1 **Work Surface**—Standing work surface and space dimensions are shown in Table 25, Fig. 65 and Fig. 66.

31.2.2 **Displays/Controls in a Standing Workplace**—Displays and controls located for use by a standing operator (for example, gage boards, bulkhead mounted, fiddle-boards, consoles, and so forth) shall be located as shown in Figs. 67-69 and as described herein.

31.2.3 **Display Placement, Normal**—Visual displays mounted on vertical panels and used in normal equipment operation shall be placed between 1.04 m (41 in.) and 1.78 m (70 in.) above the standing surface except that displays above that height are permitted, up to 2.13 m (84 in.), provided they are tilted down (see Fig. 69).

31.2.4 **Display Placement, Special**—Displays requiring precise and frequent reading shall be placed between 1.27 m (50 in.) and 1.65 m (65 in.) above the standing surface.

31.2.5 **Control Placement, Normal**—All controls (except valve handwheels) mounted on a vertical surface and used in normal equipment operation shall be located between 762 mm and 1.93 mm (30 and 76 in.) above the standing surface with a maximum height of 1.78 m (70 in.) preferred (see Fig. 69). Valve handwheels shall be located as shown in Fig. 38.
31.2.6 Control Placement, Special—Controls requiring precise or frequent operation and emergency controls shall be mounted between 860 mm and 1.35 m (34 and 53 in.) above the standing surface and no farther than 530 mm (21 in.) laterally from the centerline.

31.2.7 Window Placement—Work stations requiring vision outside through windows shall be designed so the lower edge of the window is no more than 1.3 m (52 in.) and the upper edge no less than 1.85 m (74 in.) above the deck, except for forward bridge windows which shall be no less than 1.98 m (79
Where reflection from window glass could be a problem, the window shall be angled from the vertical, top out and bottom-in, 15°, but in no case shall the angle be less than 8° or more than 25°.

31.3 Seated Operations:

31.3.1 Desk Dimensions—Dimensions for a seated desktop work station are provided in Fig. 70 and Table 26.

31.3.1.1 Work Surface Width and Depth—A lateral workspace of at least 760 mm (30 in.) wide and 400 mm (16 in.) deep shall be 740 to 790 mm (29 to 31 in.) above the floor, unless otherwise specified.

31.3.2 Writing Surfaces—Where a writing surface is required on equipment consoles, it shall be at least 400 mm (16 in.) deep and shall be 610 mm (24 in.) wide, when consistent with operator reach requirements.

31.3.3 Seating:

31.3.3.1 Compatibility—Work seating shall provide an adequate supporting framework for the body relative to the activities that must be carried out. Chairs to be used with sit-down consoles shall be designed operationally compatible with the console configuration.

31.3.3.2 Vertical Adjustment—Provision shall be made for vertical seat adjustment from 380 to 535 mm (15 to 21 in.) in increments of no more than 25 mm (1 in.) each.

31.3.3.3 Backrest—A supporting backrest that reclines between 1745 and 2005 mrad (100 and 115°) shall be provided.

<table>
<thead>
<tr>
<th>Measurement, cm (in)</th>
<th>5th % Male</th>
<th>Mean</th>
<th>95th % Percentile Male</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum body depth</td>
<td>25.7 (10.1)</td>
<td>29.2 (11.5)</td>
<td>33.0 (13.0)</td>
<td>2.2 (0.88)</td>
</tr>
<tr>
<td>Maximum body breadth</td>
<td>47.8 (18.8)</td>
<td>53.1 (20.9)</td>
<td>57.9 (22.8)</td>
<td>3.0 (1.19)</td>
</tr>
<tr>
<td>Overhead Reach</td>
<td>195.1 (76.8)</td>
<td>209.6 (82.5)</td>
<td>209.6 (82.5)</td>
<td>8.5 (3.33)</td>
</tr>
</tbody>
</table>

FIG. 59 Anthropometric Data for Body Positions Involved in Work Activities
The backrest shall engage the lumbar and thoracic regions of the back and shall support the torso in such a position that the operator’s eyes can be to the normal line of sight (Fig. 8) with no more than 75 mm (3 in.) of forward body movement.

31.3.3.4 Cushioning—Where applicable, both the backrest and seat shall be cushioned with at least 25 mm (1 in.) of compressible material and provided with a smooth surface.

31.3.3.5 Work Surface Height—Desk tops and writing tables shall be 740 to 790 mm (29 to 31 in.) above the floor, unless otherwise specified.

31.3.3.6 Armrests—Modified or retractable armrests shall be provided when necessary to maintain compatibility. Alone with an associated console and shall be adjustable from 190 to 280 mm (7.5 to 11 in.) above the compressed sitting surface.

31.3.3.7 Knee Room—Knee and foot room that equals or exceeds the following minimum dimensions shall be provided beneath work surfaces:

(a) Height: 640 mm (25 in.). If a fixed footrest or a foot-operated control is provided, this dimension shall be increased accordingly.

(b) Width: 510 mm (20 in.).

(c) Depth: 460 mm (18 in.).

31.3.3.8 Seating at Tables—For single or multiple persons sitting at tables or other nondesk-type of work stations, the dimensions shown in Fig. 71 shall be provided. Table height, knee clearance, and so forth, shall be the same as in Fig. 70.

31.3.3.9 Seating at CRT-Type Work Stations—Seating dimensions for stool or chair seating at CRT-type displays or other similar work stations is shown in Fig. 72.

31.3.3.10 Swing-Away Seats—Where permanent seats cannot be provided, swing-away seats shown in Fig. 73 shall be provided.

31.3.4 Display Placement, Normal—Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 150 and 1170 mm (6 and 46 in.) above the sitting surface.

31.3.5 Display Placement, Special—Indicators that must be read precisely and frequently shall be placed in an area between 360 and 890 mm (14 and 35 in.) above the sitting surface and no further than 530 mm (21 in.) laterally from the centerline.
31.3.6 Warning Displays—For “sit” consoles requiring horizontal vision over the top, critical visual warning displays shall be mounted at least 570 mm (22.5 in.) above the sitting surface.

31.3.7 Control Placement, Normal—All controls mounted on a vertical surface and used in normal equipment operation shall be located between 200 and 860 mm (8 and 34 in.) above the sitting surface.

31.3.8 Control Placement, Special—Controls requiring precise or frequent operation shall be mounted between 200 and 740 mm (8 and 29 in.) above the sitting surface.

31.3.9 Window Placement—Seated work stations requiring vision outside, through windows, shall be designed so the lower edge of the window shall be no higher than 1.0 m (40 in.) above the deck.

31.4 Standard Console Design:

### FIG. 61 Helmet Dimensions

<table>
<thead>
<tr>
<th>DIMENSION</th>
<th>MAXIMUM SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Length, front rim to rear rim</td>
<td>280.0 mm (11.2 in)</td>
</tr>
<tr>
<td>B. Height</td>
<td>170.0 mm (6.8 in)</td>
</tr>
<tr>
<td>C. Top of head to top of helmet</td>
<td>50.0 mm (2 in)</td>
</tr>
<tr>
<td>D. Eyebrow ridge to front rim</td>
<td>50.0 mm (2 in)</td>
</tr>
<tr>
<td>E. Width, rim to rim</td>
<td>235.0 mm (9.4 in)</td>
</tr>
</tbody>
</table>

31.4.1 Dimensions—For purposes of standardization, consoles and the units and racks that constitute operator work stations shall be designed to conform with the dimensions shown in Fig. 74 and Table 27.

31.4.2 Configurations—The configurations represented in Fig. 74 and Table 27 may not be applicable to all design situations, since, in some cases, operational requirements may necessitate unique design solutions. However, because of the benefits and economies inherent in a standard console, design shall conform with the standard configurations whenever possible.

31.4.3 Variables—The selected console design shall accommodate the following requirements, as applicable:

31.4.3.1 Visibility over the top of the console.

31.4.3.2 Operator mobility (sit, stand, or sit-stand requirements).
31.4.3.3 Panel space (note Columns “B” and “E,” Table 27).
31.4.3.4 Volume in the area below the writing surface.
31.4.4 Console Selection—On the basis of the considerations in 31.4.3, the particular configuration that will best meet the requirements shall be selected from among the console types represented in Figs. 75-77, or a special design created which meets requirements of 31.4.3 and the particular unique requirements imposed on the console, as long as the console configuration is operable and maintainable by the fifth to ninety-fifth percentile operator.

31.5 Special-Purpose Console Design:
31.5.1 One- or Two-Tier (Horizontal Wraparound):
See Fig. 75.
31.5.1.1 Panel Width—When requirements for preferred panel space for a single-seated operator exceed a panel width of 1.12 m (44 in.), a flat-surface, segmented, wraparound console shall be provided to place all controls within the reach of the fifth percentile stationary operator.
31.5.1.2 Panel Angle—The left and right segments shall be placed at an angle, measured from the frontal plane of the central segment, such that they can be reached by the fifth percentile stationary operator.
31.5.1.3 Dimensions With Vision Over Top—Where vision over the top is required, console height shall be in accordance with Table 27. The width of the central segment shall not exceed 1.12 m (44 in.), with 915 mm (36 in.) preferred, and that of the left and right segments shall not exceed 610 mm (24 in).
31.5.1.4 Dimensions Without Vision Over Top—Where vision over the top is not required, the total console height shall
be in accordance with Table 27. The width of the central
FIG. 63 Range of Human Motion (continued)
segment shall not exceed 915 mm (36 in.) and that of the left and right segments shall not exceed 610 mm (24 in.).

31.5.1.5 Viewing Angle—The total required left-to-right viewing angle shall not exceed 3.32 rad (190°). This angle shall be reduced whenever possible through appropriate control-display layout.

31.5.2 Three-Tier Flat and Wraparound (Also Called Vertical/Stacked Segments)—(See Fig. 76 for example).

31.5.2.1 Panel Division—Where direct forward vision over the top of the console is not required by a seated operator, and when lateral space is limited, the panel may be divided into three tier segments with surfaces perpendicular to the operator’s line of sight with little or no head movement.

31.5.2.2 Height—The height from the seat reference point to the centerline of the #2 tier shall be 737 mm (29 in.) preferred and 800 mm (31.5 in.) maximum. The height of the #2 tier shall be from 406 mm (16 in.) to 530 mm (21 in.) maximum. If feasible, no controls shall be placed on the third tier but displays only. If controls are placed on the third tier, they shall be reachable by a seated fifth percentile person.

31.6 Console Orientation in the Ship:

31.6.1 Propulsion, Steering, and Navigation—Operator consoles associated with control of the propulsion engines, boilers, and so forth, navigation (chart tables), and steering

---

TABLE 23 Range of Human Motion

<table>
<thead>
<tr>
<th>Body Member</th>
<th>Movement</th>
<th>Lower Limit</th>
<th>Average</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Radians (Degrees)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Wrist</td>
<td>1. Flexion</td>
<td>1.36 (78) 1.57 (90) 1.78 (120)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Extension</td>
<td>1.50 (86) 1.73 (99) 1.95 (112)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Adduction</td>
<td>0.31 (16) 0.63 (36) 0.47 (27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Abduction</td>
<td>0.70 (40) 0.94 (54) 0.82 (47)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Forearm</td>
<td>1. Supination</td>
<td>1.58 (91) 2.36 (113) 2.36 (135)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Pronation</td>
<td>0.92 (53) 1.34 (77) 1.76 (101)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Elbow</td>
<td>1. Flexion</td>
<td>2.30 (132) 2.48 (142) 2.65 (152)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Shoulder</td>
<td>1. Lateral rotation</td>
<td>0.36 (21) 0.59 (34) 0.82 (47)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Medial rotation</td>
<td>1.31 (75) 1.69 (97) 2.08 (119)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Extension</td>
<td>0.82 (47) 1.06 (61) 1.31 (75)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Flexion</td>
<td>3.07 (176) 3.28 (188) 3.32 (190)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Adduction</td>
<td>0.68 (39) 0.84 (48) 0.99 (57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Abduction</td>
<td>2.04 (117) 2.34 (134) 2.64 (151)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Hip</td>
<td>1. Flexion</td>
<td>1.75 (100) 1.97 (113) 2.20 (126)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Adduction</td>
<td>0.33 (19) 0.54 (31) 0.75 (43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Abduction</td>
<td>0.72 (41) 0.92 (53) 1.13 (65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Medial rotation (prone)</td>
<td>0.51 (29) 0.68 (39) 0.86 (49)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Lateral rotation (prone)</td>
<td>0.42 (24) 0.59 (34) 0.77 (44)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Lateral rotation (sitting)</td>
<td>0.37 (21) 0.52 (30) 0.68 (39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Medial rotation (sitting)</td>
<td>0.38 (22) 0.54 (31) 0.70 (40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Knee flexion</td>
<td>1. Prone</td>
<td>2.01 (115) 2.16 (125) 2.36 (135)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Standing</td>
<td>1.75 (100) 1.97 (113) 2.20 (126)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Kneeling</td>
<td>2.62 (150) 2.77 (159) 2.93 (168)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. Foot rotation</td>
<td>1. Medial</td>
<td>0.40 (23) 0.61 (35) 0.82 (47)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Lateral</td>
<td>0.54 (31) 0.75 (43) 0.96 (55)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. Ankle</td>
<td>1. Extension</td>
<td>0.45 (28) 0.66 (39) 0.87 (50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Flexion</td>
<td>0.49 (28) 0.61 (35) 0.73 (42)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Adduction</td>
<td>0.26 (15) 0.58 (33) 0.42 (24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Abduction</td>
<td>0.28 (16) 0.52 (30) 0.40 (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Grip angle</td>
<td>1. Dorsal (back)</td>
<td>0.77 (44) 1.06 (61) 1.54 (88)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Ventral (forward)</td>
<td>0.84 (48) 1.05 (60) 1.26 (72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Right</td>
<td>0.59 (34) 0.72 (41) 0.84 (48)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Left</td>
<td>0.59 (34) 0.72 (41) 0.84 (48)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J. Neck flexion</td>
<td>1. Right</td>
<td>1.13 (65) 1.38 (79) 1.62 (93)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Left</td>
<td>1.13 (65) 1.38 (79) 1.62 (93)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: These values are based on the nude body. The ranges are larger than they would be for clothed personnel.

Flexion: Bending or decreasing the angle between parts of the body.
Extension: Straightening or increasing the angle between parts of the body.
Adduction: Moving toward the midline of the body.
Abduction: Moving away from the midline of the body.
Medial rotation: Turning toward the midplane of the body.
Lateral rotation: Turning away from the midplane of the body.
Pronation: Rotation of the palm of the hand downward.
Supination: Rotation of the palm of the hand upward.
(especially the emergency steering system) shall be installed so the operator faces forward (in the direction of vessel movement). This shall be done whether or not the console operator has visual capability to the outside.
31.6.2 Auxiliary Machinery—Consoles controlling auxiliary machinery (ship service generators) shall be oriented so that the operator faces forward. If there is more than one auxiliary machinery room, with a control console in each, all consoles shall face in the same direction (operator facing forward preferred).

31.6.3 Damage Control, Ballast Control, and Other Consoles—Ballast or damage control consoles shall be installed so that the operator faces forward or inward from the starboard side. Other consoles may be installed in a manner best suited to placing the controls and displays on the console so that they are in direct relationship to their respective equipment’s location in the vessel.

31.7 Console Layout:

31.7.1 Spatial Relationships—Where a console contains controls and displays related to specific equipment located in a vessel, the location of the controls and displays on the console shall be in the same spatial relationship as the equipment they control or monitor. Therefore, controls and displays on the left side of the console shall be associated with equipment physically located to the left side of the console operator, and controls and displays on the right side of the console shall be associated with equipment physically located to the right side of the operator as the operator faces the console. Where a console is arranged so that the control and display arrangement correlates directly to equipment physically located in the vessel laid out from bow to stern, the controls and displays closest to the right side or top of the console shall control or monitor the equipment closest to the bow. The controls and displays at the left side or bottom of the console shall control or monitor the equipment closest to the stern.

31.7.2 Primary Displays—The primary visual surface on consoles or instrument panels shall be reserved for displays that are used frequently or are critical to successful operation. In general, this area shall correspond to the preferred viewing area shown in Fig. 78.

31.7.3 Design Principal Displays—Consoles shall follow the design principals listed below:

31.7.3.1 Indicators used for long, uninterrupted periods shall be in the primary display area.

31.7.3.2 Preferred viewing distance from the operator’s eyes to displays is 635 mm (25 in.).

31.7.3.3 Viewing distance to displays shall not be less than 250 to 300 mm (10 to 12 in.) for short viewing periods and preferably not less than 400 mm (16 in.).

31.7.3.4 Angular deviation from the operator’s line of sight up to 0.79 rad (45°) for display location is acceptable provided accurate instrument reading is not essential and parallax is not great.

31.7.3.5 Displays shall be shaped and oriented so that they correspond with the direction and magnitude of what they are representing.

31.7.3.6 Digital displays shall be used only when exact values are required and rate of change information is not required.

31.7.4 Design Principals, Controls—The optimum space for locating controls on a console (for optimum speed and accuracy of manipulation) is shown in Fig. 79. Other principals include the following:

31.7.4.1 Primary controls shall be located between shoulder level and waist height.

31.7.4.2 Controls shall be located so that simultaneous operation of two controls will not necessitate a crossing or interchanging of hands.

31.7.4.3 When controls are operated frequently, they shall be located to the left front or right of the operator.

31.7.4.4 Frequently used controls shall be grouped together, unless there are overriding reasons for separating them.

31.7.4.5 Frequently used controls shall be located for right-hand operation.

31.7.4.6 Frequently used controls shall be within a radius of 400 mm (16 in.) from the normal working position.

31.7.4.7 Occasionally used controls shall be within a radius of 500 mm (20 in.).

31.7.4.8 Infrequently used controls shall be within a radius of 700 mm (28 in.).

31.7.4.9 The movement of controls related to the ship’s motion shall correspond to the direction of desired motion.

31.7.4.10 All controls associated with ship movement shall be located so that the operator faces forward.

31.7.5 Dual Operation—Where two operators must use the same control or display (for example, in monitoring system status), the following criteria shall be applied:

31.7.5.1 If the controls and displays have high priority, duplicate sets shall be provided whenever there is adequate
31.7.5.2 If secondary controls and displays must be shared, they shall be centered between the operators if they are equally important to each operator. If the controls or displays are more important to one operator than to the other, they shall be placed nearest the operator having the principal requirements for using them.

31.7.5.3 If the primary or secondary controls must be operated with the user’s preferred hand (keyboards, keysenders, and so forth), duplicate controls must be provided. Such controls shall not be centered between the operators.

31.7.5.4 Where personnel will work from standing or seated positions, console dimensions shall conform to those of Table 27. However, where smaller consoles are provided, operators shall be spaced no closer than the dimensions shown in Fig. 71.

31.7.6 Sit-Stand Consoles—Where personnel will work from standing or seated positions, console dimensions shall conform to those of Table 27.

31.8 Stairs, Stair-Ladders, Fixed Ladders, and Ramps:

31.8.1 General Criteria:

31.8.1.1 Stairs, stair-ladders, fixed ladders, and ramps shall be provided whenever personnel must abruptly change elevation by more than 305 mm (12 in.).

31.8.1.2 Selection—The selection of stairs, stair-ladders, fixed ladders, or ramps for specific applications shall be based on the angle of ascent required and the criteria in Fig. 80.

31.8.1.3 Provision for Hand-Carrying Equipment—Ramps, elevators, or equivalent means shall be provided when equipment must be hand carried. Ladders shall not be selected in such cases, since both hands shall be free to grasp the ladder. Stairs and steps shall not be used where hand-carrying bulky loads or loads in excess of 13 kg (29 lbs) is required.

31.8.1.4 Handrails and Guardrails—Stairs, stair-ladders, fixed ladders, and ramps shall be equipped with handrails or guardrails or both as described below:

(a) Handrails—A handrail shall be installed on the enclosed side and a guardrail installed on the open side. If both sides are enclosed, handrails shall be installed on both sides if the width of the stair, stair-ladder, or ramp is more than 1118 mm (44 in.). If both sides are open, guardrails shall be installed on both sides. Stairs with three or more steps shall be equipped with handrails or guardrails. Stairs wider than 224 cm (88 in.) shall be equipped with a handrail in the center. Handrails shall be circular, not square or rectangular, and shall be of a diameter and mounting height shown in Figs. 81 and 82.

(b) Guardrails—Guardrails shall be provided at the open side of any surface whenever that surface is 610 mm (24 in.) or higher above the adjacent surface and where a person could fall from the upper to lower surface. The height of all guardrails shall be 1067 mm (42 in.) from the centerline of the top rail to the top of the walking surface. Guardrails shall have at least one intermediate rail and a toe board at least 76 mm (3 in.) high. If one intermediate rail is used, it shall be equal distance between the bottom of the top rail and the top of the toe board. A clearance of 51 mm (2 in.) minimum, 76 mm (3 in.)

### TABLE 25 Standing Work Space Dimensions for Work Clearances

<table>
<thead>
<tr>
<th>Work Clearances</th>
<th>Minimum</th>
<th>Preferred</th>
<th>Arctic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm (in.)</td>
<td>mm (in.)</td>
<td>mm (in.)</td>
</tr>
<tr>
<td>A₁, Standard bench height above floor</td>
<td>-</td>
<td>910 (36)</td>
<td>-</td>
</tr>
<tr>
<td>A₂, Podium height above floor</td>
<td>-</td>
<td>1040 (41)</td>
<td>-</td>
</tr>
<tr>
<td>B₁, Standard bench width above floor</td>
<td>-</td>
<td>990 (39)</td>
<td>-</td>
</tr>
<tr>
<td>B₂, Podium width above floor</td>
<td>-</td>
<td>1010 (39)</td>
<td>-</td>
</tr>
<tr>
<td>C, Passing body depth</td>
<td>330 (13)</td>
<td>380 (15)</td>
<td>380 (15)</td>
</tr>
<tr>
<td>D, Working space</td>
<td>635 (25)</td>
<td>910 (36)</td>
<td>-</td>
</tr>
<tr>
<td>E, Foot space</td>
<td>100 x 100 (4 x 4)</td>
<td>1950 (76)</td>
<td>2030 (80)</td>
</tr>
<tr>
<td>F, Overhead clearance</td>
<td>1855 (73)</td>
<td>685 (27)</td>
<td>635 (25)</td>
</tr>
<tr>
<td>G, Overhead reach, max</td>
<td>-</td>
<td>585 (23)</td>
<td>585 (23)</td>
</tr>
<tr>
<td>H, Depth of reach, max</td>
<td>-</td>
<td>380 (15)</td>
<td>380 (15)</td>
</tr>
<tr>
<td>I, Walking width space</td>
<td>310 (12)</td>
<td>380 (15)</td>
<td>380 (15)</td>
</tr>
<tr>
<td>J, Passing body width</td>
<td>510 (20)</td>
<td>810 (32)</td>
<td>810 (32)</td>
</tr>
</tbody>
</table>

FIG. 65 Standing Workspace Dimensions—Cabinets and Electrical Equipment Racks

FIG. 66 Standing Workspace Dimension—CRTs and Table
The recommended guardrail height between the back of the top rail and the nearest object shall be provided. Any opening between adjacent guardrails or between a guardrail and permanent structure greater than 152 mm (6 in.) shall be protected with a chain at each rail height. The chains shall be taut enough so that no more than 25 mm (1 in.) of slack is measured at the chain’s centerspan. Wherever there are changes in walking surface elevations, both of which are protected by guardrails, there shall be transition guardrails provided to protect a person moving from one elevation to another. The transition guardrail may be provided in any manner as long as it maintains the 1067-mm (42-in.) height above the walking surface used to transition between the two walking elevations. If it is possible that material could be placed in an area protected by a guardrail to such a height that the toeboard would not prevent its passing through the guardrails and falling to a lower level, then between rail protection via expanded metal screen, netting, or bars.

**NOTE:** Reduce height values 12.7 cm (5 in) for comfortable use by women.

**FIG. 67 Standing Workspace Dimensions—Consoles and Work Benches**
other suitable material shall be added between the rails to a height equal to that of the expected stacked material.

31.8.2 Tread Color Marking—25 mm (1 in.) at the leading edge of each tread and the face of the tread shall be painted red or yellow (yellow preferred) to make the front edge of each tread visually distinctive from the rest of the tread surface.

31.8.3 Stairs—Stair dimensions shall conform with the recommended values and shall be within the minimum and maximum limits of Fig. 81. Long flights of stairs shall be avoided. There shall be at least one landing for each story 2.44 to 3.66 m (8 to 12 ft) of elevation change, and landings are recommended every ten to twelve treads. Each landing shall be
a minimum of the stairway width and a minimum of 915 mm (36 in.) and a maximum of 1220 mm (48 in.) long measured in the direction of travel. Treads shall be open unless screens or kick plates are required to protect personnel or equipment under the stairs. When personnel carry loads weighing more than 9 kg (20 lbs), or where stairs are more than two stories high, use deep treads, 300 mm (12 in.) and low risers, 125 mm (5 in.).

---

<table>
<thead>
<tr>
<th>CM</th>
<th>INCHES</th>
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</thead>
<tbody>
<tr>
<td>213.4</td>
<td>84</td>
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<tr>
<td>198.1</td>
<td>78</td>
</tr>
<tr>
<td>182.9</td>
<td>72</td>
</tr>
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<td>167.6</td>
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</tr>
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<td>162.4</td>
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<td>137.2</td>
<td>54</td>
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<tr>
<td>106.7</td>
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<tr>
<td>91.4</td>
<td>36</td>
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<tr>
<td>76.2</td>
<td>30</td>
</tr>
<tr>
<td>61.0</td>
<td>24</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>CM</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.7</td>
<td>18</td>
</tr>
<tr>
<td>30.5</td>
<td>12</td>
</tr>
</tbody>
</table>

*Emergency controls should be no more than 53.3 cm (21 in) lateral from centerline of the operator's body.*

---

**FIG. 69 Display (Top) and Control (Bottom) Locations for Standing Crew Work Stations**
31.8.4 **Incline Ladders**—Incline ladder dimensions shall conform with the recommended values and shall be within the specified minimum and maximum limits of Fig. 82. The tread rise shall be open at the rear. Landings shall be provided every tenth or twelfth tread. The surface of treads on exterior stair ladders shall be constructed of open grating material or shall be
31.8.5 Vertical Ladders—Vertical ladder dimensions shall conform with the recommended values and shall be within the specified minimum and maximum limits of Fig. 83 except that rung spacing shall be equal throughout the length of the ladder and the top rung shall be even with the top landing. Ladder stringers shall be 28 to 51 mm (1 1/2 to 2 in.) in diameter. Flat bar shall not be used for ladder stringers.

31.8.5.1 Ladder Clearances—For ladders without cages, the minimum perpendicular horizontal clearance from the rung centerline to the nearest obstruction on the climbing side shall be 762 mm (30 in.). Overhead clearance above the top rung of the ladder shall be 2032 mm (80 in.). The minimum horizontal distance from the ladder centerline to the nearest obstruction on either side of a ladder shall be 381 mm (15 in.). The step-across distance from the back of the ladder rung to the nearest edge of the top landing shall be not less than 64 mm (2 1/2 in.) nor more than 254 mm (10 in.).

31.8.5.2 Ladder Heights—Maximum heights of unbroken ladders shall be 9.12 m (30 ft). Where vertical ladder heights exceed 9.12 m (30 ft), intermediate landings and separate, multiple ladder runs of equal length shall be provided. Exceptions to this requirement are allowed where space does not provide for separate ladder runs, and approval is given by the organization or agency acquiring the ladders to waive this requirement, and the ladder is equipped with a positive climber fall protection device.

31.8.5.3 Ladder Horizontal Spacing—Horizontal spacing between ladder sections described above shall not exceed 457 mm (18 in.) at the point where the climber moves from one ladder section to another.

31.8.5.4 Safety Gates—A self-closing safety gate covering the full width of the vertical ladder opening shall be installed at the top of each vertical ladder.

31.8.5.5 Ladders as Work Platforms—Ladders attached to tanks, pressure vessels, structure, or any object to provide access to a work site that requires the worker to work from the ladder shall be equipped with either a dedicated work platform, a climber safety rail, or a permanent attachment point on the tank, vessel, or structure so the worker can safely secure himself with his climbing harness while completing his tasks.

31.8.5.6 Special Ladder Requirements—Any permanent vertical ladder, regardless of its height, located within 1.84 m (6 ft) of the edge of a deck level which is higher than 914 mm (36 in.) above an adjacent level (measured from the ladder centerline to the break in the deck elevations) shall be equipped with a climber fall safety device to prevent a worker from falling from the ladder to the lower level.

31.8.5.7 Climber Fall Protection Device—Climber fall protection devices shall be installed on all vertical ladders exceeding 4.45 m (15 ft), and positive protection devices (that is, safety rails, cables, bars) shall be installed on all vertical ladders 7.4 m (25 ft) or higher whether they are equipped with cages or not. Where cages are used, they shall extend 914 mm (36 in.) minimum and 1067 mm (42 in.) preferred above the top landing. Climber safety rails, cables, and bars shall run continuously beginning 914 mm (36 in.) above the standing surface at the bottom of the ladder to 1067 mm (42 in.) above the standing surface at the top landing.

31.8.6 Steps—Individual steps, comprised of a tread surface attached directly to a structure, may be used to change vertical elevations anywhere the total rise in height between waling surfaces does not exceed 610 mm (24 in.) and where a stair or ramp is not practical.

31.8.7 Individual Ladder Rungs—Individual circular bar rungs may be attached directly to a bulkhead, tank, or steel structure and used as a vertical ladder provided that the change in vertical height is 3 m (10 ft) or less and that all design requirements for vertical ladder rungs provided in Fig. 83 are satisfied.

31.8.8 Stair and Ladder Attachment—Stairs and ladders may be pinned at the top and bottom for easy removal in locations where their removal would enhance ease of equipment removal for maintenance or replacement. However, stairs or ladders that serve as a required means of egress in emergencies shall be permanently installed.

31.8.9 Spiral Stairs—Spiral stairs shall not be permitted except on tanks or other round structures whose diameter is greater than 2.4 m (8 ft) and when a normal stair design is not practical.

31.8.10 Ramps:

31.8.10.1 Cleating—Where special environmental conditions require cleating of pedestrian ramps, the cleats shall be spaced 360 mm (14 in.) apart and extend from handrail to handrail at right angles to the line of traffic.
31.8.10.2 Mixed Traffic—When a ramp is required for both pedestrian and vehicle traffic, the vehicle-bearing surface shall be located in the center of the ramp, with the pedestrian surface next to the handrails. (A vehicle ramp with an adjacent pedestrian stairway is preferred for this situation.) From the standpoint of space and speed, stairways carry pedestrian traffic more efficiently than ramps do.

31.8.11 Personnel Platforms and Work Areas—The surfaces of exterior personnel platforms and work areas shall be constructed of open metal grating. Exterior personnel platforms, for which utilization of open grating is impractical, and interior walkways shall be treated with nonskid material. All open sides of personnel platforms shall be equipped with guardrails (with intermediate rails), with a top rail height not less than 1.070 m (42 in.) and a toeboard or guard screen height not less than 75 mm (3 in.). Handholds shall be furnished where needed. The distance between the platform edge and the centerline of the railing shall not exceed 65 mm (2.5 in.).

31.8.12 Elevated Work Platform—Where these items are required, the following shall be provided:

31.8.12.1 Maximum load signs, located where they can be easily seen.

31.8.12.2 Guards, to prevent accidental operation of the lift.

31.8.12.3 Limit stops, to prevent injury to personnel and damage to equipment.

31.8.12.4 An automatic failsafe brake or other self-locking device in case of lift mechanism failure.

31.8.12.5 Provision for manually lowering the platform or elevator when feasible.
31.8.12.6 Surface construction or treatment of open platforms, in accordance with 31.8.11.
31.8.12.7 Provision of a work space at least 762 mm (30 in.) wide and 915 mm (36 in.) long.
31.8.12.8 Ability to hold one or two persons (not more than two).
31.8.12.9 Ability to hold the heaviest combination of equipment and personnel (use 250 lbs (118.4 kg)) for each person. A well-designed work platform is shown in Fig. 84.
31.8.12.10 Work platforms shall be located whenever possible so the worker performs his task at the height of 965 to 1270 mm (38 to 50 in.) above the standing surface of the platform.

31.9 Ingress and Egress:
31.9.1 Doors—Sliding or vertical doors are recommended for large vehicles, pieces of equipment, or cargo that must be moved into or out of a compartment. Separate hinged doors shall be inserted into the sliding or vertical doors for personnel use. However, vertical or sliding doors must never be the only exit from an area. There must always be another way to escape. Door dimensions shall be as shown in Fig. 85.
31.9.2 Hatches—Hatches shall be flush with the floor where structural considerations will permit this arrangement.
31.9.2.1 Operation—Hatches shall open with a single motion of the hand or foot.

31.9.2.2 Force Requirements—When a handle is used for unlocking a hatch, the unlocking force required shall not exceed 90 N (20 lbs). Hatches placed in the overhead position shall require no more than 220-N (50-lbs) force for opening and closing and shall be operable by a suitably equipped and clothed user with fifth percentile arm and hand strength. The force of gravity shall be used, where possible, for ease of opening.
31.9.2.3 Locking Mechanisms—Hatches shall have a locking mechanism such that the hatch is locked in the open position as soon as the hatch opens 1.57 rad (90°). The latching mechanism shall require a deliberate effort by a crew member to override before the hatch can be closed. Further, the locking mechanism shall be designed so that the hatch cannot close inadvertently during severe ship motion or wear on the locking mechanism.
31.9.2.4 Access—When an overhead hatch is reached via a ladder, the edge of the hatch opening shall be no more than 203 mm (8 in.) from the face of the ladder rung (see Fig. 86). Hatches mounted in vertical walls shall be sized and located as shown in Fig. 87.
31.9.2.5 *Dimensions*—Hatches shall be sized and located to accommodate the suitably equipped and clothed fifth to ninety-fifth percentile user. Recommended hatch dimensions are shown in Fig. 88 and shall be used unless otherwise specified.

31.9.2.6 *Kick-Out Hatches*—Emergency escape kick-out hatches shall be provided in spaces where it is impractical or impossible to provide a second door or hatch for emergency escape. The kick-out panels shall be clearly marked on both sides, and shall not be covered by furniture, cabinets, equipment, or any other item that could prevent direct and unobstructed access to the panel. Kick-out panels shall be sized and located to accommodate the fifth to ninety-fifth percentile person easily, but in no case shall they be smaller than 725 mm (28 in.) wide and 850 mm (34 in.) high.

31.9.2.7 *Whole-Body Access*—Where rescue of personnel may be required because of environmental hazards (for example, toxic fumes) within the work place, larger access openings for two-person ingress and egress may be necessary. Where step down through a top access exceeds 690 mm (27 in.), appropriate foot rests or steps shall be provided.

31.9.3 *Passing Openings*—Openings provided between compartments for passing printed information by a seated operator shall be between 610 to 635 mm (24 to 25 in.) above the deck. For standing operators, they shall be 920 to 1520 mm (36 to 60 in.) above the deck.

31.10 *Walkways and Passageways*:

31.10.1 *Dimensions*—In machinery spaces, store rooms, and other areas of limited space, the following dimensions shall be provided for walkways and passageways:

31.10.1.1 For one person to walk sideways, 330 mm (13 in.), 410 mm (16 in.), when wearing bulky clothing.

31.10.1.2 For one person to walk forward, minimum walking envelope is shown in the top illustration of Fig. 89. However, where grated walkways or passageways are provided, they shall be at least 510 mm (20 in.) wide and 760 mm (30 in.) if possible. Major passageways for two-way pedestrian traffic shall be a minimum of 914 mm (36 in.) wide. No items (for example, circuit breakers, electrical junction boxes, battle lanterns, and so forth) shall be mounted on the walls or bulkheads of these passageways to reduce the effective width of the passageway less than 914 mm (36 in.). If such items must be mounted to a bulkhead, they shall be mounted as shown. Every effort shall be made to install items 1960 mm (77 in.) or more above the standing deck level. T-butts and other deck mounted equipment with raised foundations shall be recessed into the walkway grating whenever clear walkway widths would be less than 914 mm (36 in.) with the raised foundations.

31.11 *Miscellaneous Work Station Design Requirements*:

31.11.1 *Hand Pumps*—Hand pumps shall be installed so the lowest point of travel for the handle is no lower than 635 ± 25 mm (25 ± 1 in.), nor higher than 1168 ± 25 mm (46 ± 1 in.) above the level on which the pump operator stands. Gratings or other permanent footing shall be provided in front of hand pumps. Hand pumps shall be located so that no obstacles (equipment, piping, guardrails, rotating shafts, and so forth) are between the pump and the pump operators. Where a hand pump is capable of, or required, to be operated by two persons simultaneously, provide sufficient room for both operators to work. Hand pumps shall be located so that the pump face is parallel with the operator’s body (the operator faces the pump handle). Clearance shall be provided around the pump to permit the operator’s body to move during the cranking operation.

31.11.2 *Phone Booths*—Phone booths shall be turned so the opening is at least 1.57 rad (90°) from the noise source. Desk surface of phone booths shall be 94 to 104 cm (37 to 41 in.) above the standing surface. A minimum of 46-cm (18-in.) clearance between the booth face and any obstruction in front of the booth shall be provided.

---

**TABLE 27 Standard Console Dimensions**

<table>
<thead>
<tr>
<th>Type of Console</th>
<th>Maximum Total Console Height from Standing Surface A (m (in.))</th>
<th>Suggested Vertical Dimension of Panel (Including Sills) B (mm (in.))</th>
<th>Writing Surface: Shelf Height from Standing Surface C (mm (in.))</th>
<th>Seat Height from Standing Surface at Midpoint of G D (mm (in.))</th>
<th>Maximum Console Width (Not Shown) E (mm (in.))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sit (with vision over top)*</td>
<td>1.170 (46.0)</td>
<td>520 (20.5)</td>
<td>650 (25.5)</td>
<td>435 (17.0)</td>
<td>1120 (44.0)</td>
</tr>
<tr>
<td>2. Sit (without vision over top)</td>
<td>1.435 (56.5)</td>
<td>520 (20.5)</td>
<td>910 (36.0)</td>
<td>695 (27.5)</td>
<td>1120 (44.0)</td>
</tr>
<tr>
<td>3. Sit-stand (with standing vision over top)</td>
<td>1.570 (62.0)</td>
<td>660 (26.0)</td>
<td>910 (36.0)</td>
<td>695 (27.5)</td>
<td>910 (36.0)</td>
</tr>
<tr>
<td>4. Stand (with vision over top)</td>
<td>1.570 (62.0)</td>
<td>660 (26.0)</td>
<td>910 (36.0)</td>
<td>695 (27.5)</td>
<td>910 (36.0)</td>
</tr>
<tr>
<td>5. Stand (without vision over top)</td>
<td>1.830 (72.0)</td>
<td>910 (36.0)</td>
<td>910 (36.0)</td>
<td>910 (36.0)</td>
<td>910 (36.0)</td>
</tr>
</tbody>
</table>

*The range in "A" is provided to allow latitude in the volume of the lower part of the console; note relationship to "C" and "D."*
31.11.3 Deck Machinery Control:
31.11.3.1 Control Pedestals—Controls mounted on pedestals shall be 104 cm (41 in.) above the deck. Control pedestals for boat davit operation shall be located so that the operator faces the davit but within 76 cm (30 in.) of the emergency brake on boat davit wrench. The pedestal shall be located so that the operator can see the boat in the water.

31.11.3.2 Stores and Cargo Handling—Doors at the load-unload stations for vertical package conveyors, dumbwaiters, and elevators shall open 2.09 rad (120°). Control stations for elevators, package conveyors, and dumbwaiters shall be located on the side of the door opposite the hinges, or above the door opening, and shall be placed so that the operator has an unobstructed view into the trunk when the doors are open. For double-door elevators, the controls shall be located so that the operator has direct access to the emergency shutoff button with the doors open, yet allows the operator to see into the trunk with the doors open. Control stations shall be mounted so that no control is less than 102 cm (40 in.), or more than 152 cm (60 in.), above the deck (for control stations located beside the door) and no higher than 193 cm (76 in.) for stations placed above the door.

31.11.3.3 Emergency Stop Buttons—Emergency stop buttons for deck cranes elevators, vertical package conveyors, and other similar machinery shall be mounted between 114 cm (45 in.) and 135 cm (53 in.) above the deck. They shall be red in color, clearly labeled, and free of any nearby obstructions.

31.11.3.4 Anchor Controls—Speed and brake handwheel controls shall be between 102 to 107 cm (40 to 42 in.) above the deck and at least 61 cm (24 in.) from adjacent ship structures, pipes, and so forth. A 97-cm (38-in.) high safety shield shall be installed between the controls and anchor windlass and capstan.

31.11.3.5 Shore Power Connectors—Shore power connectors shall be no higher than 165 cm (65 in.) above the deck. Connector cables shall be stored as close to the connectors as possible and at least on the same deck level.

32. Environment
32.1 General—To maximize the effectiveness of the human operator/maintainer, the designer must consider the environmental limits to which the system and the human being will be subjected and the potential impact this environment can have on the performance of both the hardware and the human. Once
the designer has identified the limits of the environment (noise, temperature, fumes, vibration, and so forth), the information contained herein shall be used to determine if, and to what extent, the human being can perform the required tasks.

32.2 Temperature:

32.2.1 Effective Temperature Defined—The effective temperature (ET) of an environment is an empirical thermal index that considers how combinations of dry-bulb air temperature, humidity, air movement, and clothing affect people. This temperature may be read from Fig. 90. This chart is based on wearing customary indoor clothing and doing sedentary or light muscular work. It does not include any additional heat stresses from special purpose clothing such as gas masks, chemical protective clothing, or body armor. Likewise, it does not consider radiant heat inputs such as radiation from the sun or equipment components.

32.2.1.1 Maximum Effective Temperature (Air Conditioning)—A maximum effective temperature of 29.5°C (106.5°F) shall be considered for reliable human performance. When air-conditioning systems are necessary to obtain this temperature, they shall be designed such that cold-air discharge is not directed on personnel. The flow of cold air passing the person shall be between 9.1 to 13.7 m (30 to 45 ft) per minute.

32.2.1.2 Minimum Effective Temperature (Heating)—Minimum temperature requirements are dependent upon the tasks to be performed in specific applications. However, within permanent and semipermanent facilities, an effective temperature (ET) of not less than 18°C (65°F) shall be maintained unless dictated otherwise by heavy workload or extremely heavy clothing. When heating systems are provided to maintain this minimum effective temperature, they shall be designed so hot air is not directly discharged on the personnel. Heating shall be provided within mobile personnel enclosures used for detailed work or occupied during extended periods of time to maintain interior dry bulb temperature above 10°C (50°F).

32.2.2 Optimum Effective Temperatures—For maximum physical comfort while normally dressed appropriate to the season climate, the optimum range of effective temperature for accomplishing light work shall be the following:

32.2.2.1 In a warm climate or during summer, 21 to 24°C (70 to 75°F).

32.2.2.2 In a colder climate or during winter, 18 to 21°C (64 to 70°F).

32.2.3 Temperature Variance—The temperature of the air at floor level and at head level shall not differ by more than 5.5°C (10°F). Sidewalls of a compartment shall be kept at equal temperatures insofar as possible with differences of 5°F (11°C) being the maximum allowed.

32.2.4 The effect of temperatures on the physical and mental performance of human beings is shown in Tables 28-30.

32.3 Humidity—Humidity shall be maintained between 20 and 60 % with 40 to 45 % preferred. A good design goal is 45 % relative humidity provided at 21°C (70°F). This value shall decrease with rising temperatures, but shall remain above 20 % to prevent irritation and drying of body tissues, eyes, skin, and respiratory tract. Tolerable humidity-temperature zones are shown in Fig. 90.
FIG. 79 Seated Optimum Manual Control Space
32.4 Wind and Windchill—Fig. 91 depicts the relationship between temperature and wind for various windchill values. Fig. 92 gives the cooling power of wind expressed as “Equivalent Chill Temperature.” Frostbite can occur even in relatively warm temperatures if wind penetrates the layer of insulating air around the body to expose body tissue. A qualitative description of human reaction to windchill values to exposed skin is given in Table 31.

32.5 Thermal Tolerance and Comfort Zones—Temperature and humidity exposure shall not exceed the effective temperature limits given in Fig. 90 when corrected for air velocity (Fig. 91).

32.6 Personal Equipment Thermal Control—When special protective clothing or personal equipment, including full and partial pressure suits, fuel handler suits, body armor, arctic clothing, and temperature-regulated clothing are required and worn, a comfort microclimate between 20°C (68°F), 14-mm (0.6-in.) mercury ambient water vapor pressure and 35°C (95°F), 3-mm (0.1-in.) mercury ambient water vapor pressure is desirable and, where possible, shall be maintained by heat transfer systems.

32.7 Limited Thermal Tolerance Zones—Where hard physical work is to be required for more than 2 h, an environment not exceeding a WBGT or WD index of 25°C (77°F) shall be provided. Where the wearing of protective clothing systems (which reduce evaporation of sweat from the skin) is required, this index shall be decreased 5°C (10°F) for complete chemical protective uniforms, 4°C (7°F) for intermediate clothing systems, and 3°C (5°F) for body armor.

32.8 Ventilation—Adequate ventilation shall be assured by introducing fresh air into any personnel enclosure. If the enclosure volume is 4.25 m³ (150 ft³) or less per person, a minimum of 0.85 m³ (30 ft³) of ventilation air per minute shall be introduced into the enclosure; approximately two thirds shall be outdoor air. For larger enclosures, the air supply per person may be in accordance with the curves in Fig. 93. Air shall be moved past personnel at a velocity not more than 60 m (200 ft) per minute. Where manuals or loose papers are used, airspeed past these items shall be not more than 30 m (100 ft) per minute—20 m (65 ft) per minute if possible, to preclude
pages in manuals from being turned by the air or papers from being blown off work surfaces. Under NBC conditions, ventilation requirements shall be modified as required. Ventilation or other protective measures shall be provided to keep gases, vapors, dust, and fumes within the permissible exposure limits specified by 29 CFR 1910 and the limits specified in the American Conference of Governmental Industrial Hygienists Threshold Limit Values.

32.8.1 CBR Ventilation—Under chemical-bacteriological warfare, all air used for breathing and ventilation will require filtration. Under these conditions, the ambient air temperature can raise as much as 0.75°C (1.5°F). For sedentary persons, a minimum of 0.1 m³ per minute of intake air will provide adequate oxygen and acceptable carbon dioxide concentration.

32.8.2 Ventilation Intakes/Outlets—Intakes for ventilation systems shall be located to minimize the introduction of contaminated air from such sources as exhaust pipes. Ventilation outlets in machinery spaces shall not be located so that air is discharged directly into an access opening for the engine, reduction gear, or other moving machinery.

32.9 Illuminance—Where equipment is to be used in enclosures and is not subject to blackout or special low-level lighting requirements, illumination levels shall be as specified by Table 32 and shall be distributed so as to reduce glare and specular reflection. Capability for dimming shall be provided. Adequate illumination shall be provided for maintenance tasks. General and supplementary lighting shall be used, as appropriate, to ensure that illumination is compatible with each task situation. Portable lights shall be provided for personnel performing
visual tasks in areas where fixed illumination is not provided. For display lighting, see Table 33.

32.10 Reflectance:
32.10.1 General—Large surface areas shall be covered with nonsaturated colors such as tints, pastels, and warm grays that are nonglossy. Some noncritical small areas such as door frames and molding may be glossy if ease of cleaning is essential.

32.10.2 Surface Reflectance Values—Generally recommended surface reflectance values for work places such as control rooms, offices, and maintenance areas are indicated in Fig. 94.

32.11 Dark Adaptation:
32.11.1 General—Dark adaptation is the process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 min, but the time required for dark adaptation depends on the color curvature of exposure and intensity of the previous light.

32.11.2 White Light—Low-level white light is as compatible for dark adaptation as is red light and permits the use of color coding. Colors often appear different under different types of illumination; so, unless a display will always be used under white light, do not use color coding.

32.11.3 Red Light—Red light may be used to do visual work and for instrument and display markings between 0.07 cd/m² (0.02 ft·L) and 0.35 cd/m² (0.1 ft·L) where maintaining maximum dark adaptation is required. This red light is obtained by passing white light through a filter that transmits only wavelengths longer than 620 mm (24 in.) (red).

32.11.4 Green Light—Where detection by enemy image intensifier night vision devices is a threat or where night vision goggles could be worn by operating personnel while viewing displays or working in a dark adaptive environment, a low-density blue-green light (incandescent filament through a high pass filter with a 600-NM cutoff) may be used for control/display or space lighting.

32.12 Acoustical Noise:
32.12.1 General—Personnel shall be provided an acoustical environment that will not cause personnel injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade overall system effectiveness. The fact that a component which contributes to the overall noise may be government furnished equipment shall not eliminate the requirement that the total system conform to the criteria herein.

32.12.2 Hazardous Noise—Equipment shall not generate noise in excess of maximum allowable levels prescribed herein for the various frequency ranges (see Tables 34-37).
Nonhazardous Noise—Workspace noise shall be reduced to levels that permit necessary direct (person-to-person) and telephone communication and establish an acceptable acoustical work environment. Criteria for workspaces are defined by either the A-sound level (dB(A)) or the preferred speech interference level (PSIL) and are given in 32.12.3.1-32.12.3.6. The A-sound level is the desired requirement. Where it is not possible to meet the specified A-sound level, the corresponding PSIL requirement shall be met. Fig. 95 provides guidance on the relationship between required vocal-effort, speaker-to-listener distance and noise level.

32.12.3.1 General Workspaces—Areas requiring occasional telephone use or occasional direct communication at distances up to 1.5 m (5 ft) shall not exceed 75 dB(A) or 67 dB PSIL or 68 dB PSIL. (Examples: maintenance shops and shelters and shipboard engineering areas.)

32.12.3.2 Operational Areas—Areas requiring frequent telephone use or frequent direct communication at distances up to 1.5 m (5 ft) shall not exceed 65 dB(A) or 57 dB PSIL or 58 dB PSIL. (Examples: operation centers, communication centers, combat information centers, and word processing centers.)

32.12.3.3 Large Workspaces—Areas requiring no difficulty with telephone use or requiring occasional direct communication at distances up to 4.6 m (15 ft) shall not exceed 55 dB(A) or 47 dB PSIL or 48 dB PSIL.

32.12.3.4 Small Office Spaces Special Areas—Areas requiring no difficulty with direct communication shall not exceed 40 dB(A) or 42 dB PSIL or 38 dB PSIL. (Examples: libraries, offices, and command and control centers.)

32.12.3.5 Extreme Quiet Area—Areas requiring extreme quiet shall not exceed 35 dB(A) or 27 dB PSIL or 33 dB PSIL. (Example: medical wards.)

32.12.3.6 Shipboard Areas—Shipboard areas requiring a specified speech communication environment shall not exceed 5 dB above the levels shown in 32.12.3.1-32.12.3.5. Levels for spaces and categories not covered in these paragraphs shall be as given in the detailed shipbuilding specification, or established from the information provided in Tables 38-41.

32.12.4 Facility Design:

32.12.4.1 General Provision—In the design of a workspace or facility, the ambient noise level shall be controlled to the extent feasible through effective sound reduction or attenuation to meet the criteria herein.
TABLE 29 Physical and Perceptual Responses to Various Temperatures

<table>
<thead>
<tr>
<th>Temperature of Skin, °C (°F)</th>
<th>Perceptual Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 (98)</td>
<td>Very hot</td>
</tr>
<tr>
<td>36 (96)</td>
<td>Unpleasantly warm</td>
</tr>
<tr>
<td>35 (94)</td>
<td>Slightly warm</td>
</tr>
<tr>
<td>34 (93)</td>
<td>Comfortable</td>
</tr>
<tr>
<td>33 (91)</td>
<td>Comfortably cool</td>
</tr>
<tr>
<td>31 (88)</td>
<td>Slightly too cool</td>
</tr>
<tr>
<td>30 (86)</td>
<td>Unpleasantly cool</td>
</tr>
<tr>
<td>29 (84)</td>
<td>Very cold</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature of Surface, °C (°F)</th>
<th>Physical Response</th>
<th>Sensation of Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 (212)</td>
<td>Second-degree burn on 15-s contact</td>
<td></td>
</tr>
<tr>
<td>82 (180)</td>
<td>Second-degree burn on 30-s contact</td>
<td></td>
</tr>
<tr>
<td>71 (160)</td>
<td>Second-degree burn on 60-s contact</td>
<td></td>
</tr>
<tr>
<td>60 (140)</td>
<td>Pain; tissue damage</td>
<td></td>
</tr>
<tr>
<td>49 (120)</td>
<td>Pain; burning heat</td>
<td></td>
</tr>
<tr>
<td>33 (91)</td>
<td>Warm; neutral (physiological zero)</td>
<td></td>
</tr>
<tr>
<td>12 (54)</td>
<td>Cool</td>
<td></td>
</tr>
<tr>
<td>3 (37)</td>
<td>“Cool heat” sensation</td>
<td></td>
</tr>
<tr>
<td>0 (32)</td>
<td>Pain</td>
<td></td>
</tr>
<tr>
<td>Below 0 (32)</td>
<td>Pain; tissue damage (freezing)</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 30 Temperature and Its Effect on the Comfort of the Extremities

<table>
<thead>
<tr>
<th>Skin Temperature, °C (°F)</th>
<th>Hands</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum acceptable</td>
<td>20 (68)</td>
<td>23 (73)</td>
</tr>
<tr>
<td>Tolerable</td>
<td>20–15 (68–59)</td>
<td>23–18 (73–64)</td>
</tr>
<tr>
<td>Intolerable</td>
<td>10 (59–50)</td>
<td>18–13 (64–55)</td>
</tr>
<tr>
<td>Numbness sets in</td>
<td>&lt;10 (&lt;50)</td>
<td>&lt;13 (&lt;55)</td>
</tr>
</tbody>
</table>

32.12.4.2 Attenuation by Materials and Layout—Acoustic materials with high sound-absorption coefficients shall be provided in the construction of floors, walls, and ceiling to effect the required sound control. In the physical design and layout of rooms and work stations, excessive noise shall be attenuated by such means as staggered construction of walls, staggering of doors in corridors or between rooms, and use of thick-paned or double-paned windows.

32.12.5 Reduction of Reverberation Time—When speech communication is a consideration, the acoustical treatment of facilities shall be sufficient to reduce reverberation time, to the applicable limits of Fig. 96.

32.13 Vibration:

32.13.1 Vehicular Vibration—Vehicles or facilities for use on land or sea shall be designed to control the transmission of whole body vibration to levels that will permit safe operation and maintenance as shown in Fig. 97 (see ISO 2631). In the case of multidirectional vibration, each direction shall be evaluated independently with respect to the limits presented.

32.13.2 Whole Body Vibration:

32.13.2.1 Safety Level—To protect human health, whole body vibration shall not exceed twice the acceleration values shown on Fig. 97 for the time and frequencies indicated.

32.13.2.2 Proficiency Level—Where proficiency is required for operational and maintenance tasks, whole body vibration shall not exceed the acceleration values shown on Fig. 97 for the time and frequencies indicated.

32.13.2.3 Comfort Level—Where comfort is to be maintained, the acceleration values shown on Fig. 97 shall be divided by 3.15.

32.13.2.4 Motion Sickness—To prevent motionsickness, very low-frequency vibration shall not exceed the limits of Fig. 98.

32.13.3 Building Vibration—Facilities intended for occupation by humans shall be designed/located to control the transmission of whole body vibration levels that are acceptable to the occupants as specified by ISO 2631.

32.13.4 Equipment Vibration—Where whole body vibrations of the human operator or parts of the body are not a factor, equipment oscillations shall not impair human performance with respect to control manipulations or the readability of numerals or letters. Equipment vibrations in the upper figure of Fig. 97 shall be avoided.

32.14 Noxious Substances:

32.14.1 General—Enclosed crew compartments shall not be susceptible to accumulations of noxious substances generated by shipboard activities (diesel engine and gas turbine exhaust, firing of weapons, and so forth). From the practical standpoint of controlling health hazards, the critical contaminants are carbon monoxide, ammonia, nitrogen oxides, sulphur dioxide, and aldehydes (for example, methane). Other contaminants may also create health hazards, particularly when design changes are introduced or new fuels or propellants are used.

32.14.2 Carbon Monoxide, Ammonia, Nitrogen Dioxide—Carbon monoxide (CO) is particularly dangerous in that it is odorless, colorless, and tasteless and is not ordinarily detectable by the human senses. Excessive exposure can cause loss of mental alertness, disorientation, collapse, and even death. Its effects are cumulative, and doses that may be tolerable by individuals for brief periods can be ultimately dangerous when repeated often over several hours. Ammonia is a pulmonary irritant and asphyxiant and even in small concentrations can cause eye discomfort and watering. Nitrogen dioxide is both a pulmonary irritant and edemogenic agent.

32.14.3 Nitrogen Oxides—Nitrogen oxides can be dangerous because they produce relatively little discomfort, yet even low concentrations can produce grave damage in the lower respiratory tract. Thus, exposed personnel may experience slight irritation while breathing concentrations of nitrogen oxides which will, 12 to 24 h later, prove fatal.

32.14.4 Aldehydes—Aldehydes can cause eye irritation, conjunctivitis, and nausea, causing temporary disability.

32.14.5 Concentrations—The presence of either carbon monoxide or ammonia in concentrations, in excess of that shown below can reduce the effectiveness of personnel and even cause collapse and unconsciousness. Current limits, expressed as a time-weight average (TWA), are as follows:

32.14.5.1 Carbon Monoxide (CO)—25 parts per million (ppm).

32.14.5.2 Ammonia (NH₃)—5 parts per million (ppm).

32.14.5.3 Nitrogen Dioxide (NO₂)—5 parts per million (ppm). The NO₂ limit particularly shall not be exceeded at any time.
32.14.6 Weapon Fumes—The fumes produced when weapons are fired contain carbon monoxide (approximately one third of the volume of fumes produced), oxides of nitrogen, and ammonia.

32.14.7 Exhaust Fumes—The exhaust products of carbon monoxide and carbon dioxide occur no matter which fuel is used.

32.14.7.1 When multifuel engines are using gasoline, the exhaust products include nitrogen, oxygen, and hydrogen.

32.14.7.2 When these engines are operated on CITC, JP4, JP5, or kerosene, the exhaust products include aldehydes, water, hydrogen, and free carbon.

32.14.7.3 When diesel fuel is used, the exhaust products include aldehydes, traces of nitrogen oxides, sulphur compounds, oxygen, nitrogen, and methane. Table 42 shows some of the noxious exhaust products of engine fuels.

32.14.7.4 Ventilation—Careful consideration shall be given in designing compartments where vehicles could be stored and run (such as the well deck of an amphibious ship) to provide sufficient ventilation level, and the direction and dispersion of these products (the exhaust of multifuel engines) shall minimize exhaust concentrations.

32.15 Protection Against Chemical Warfare Agents:

32.15.1 Basic Protection—Ship designs shall be such that in the event of employment of chemical warfare agents, the first consideration must be the adequate protection of the crew members and, second, the maintenance of the ability to
continue operations. The three basic ways to provide protection against CW agents are as follows:

32.15.1.1 Individual Protection—Generally consists of a protective mask, protective clothing, and perhaps a decontamination kit.

32.15.1.2 Collective Protection, Operator or Crew Station—Each operator or crew member wears a protective mask connected to a centrally located gas particulate filter. The operator may or may not require protective clothing.

32.15.1.3 Collective Protection, Overpressure—The collective protection system (CPS) provides an overpressure in the entire personnel-occupied compartment. Protection masks and clothing are not required to be worn if the CPS is operating properly. Selection of the best method to provide protection against CW agents must be based upon the operational considerations, cost effectiveness, and the requirements documentation.

32.15.2 General—For personnel required to be in the environment during the accomplishment of their duties, the protective ensemble is the only feasible way to accomplish the required protection. For other situations, a choice between crew or operator station collective protection and overpressure collective protection must be made.

32.15.3 Overpressure Collective Protection System (CPS)—Whereas all three methods will protect personnel, the CPS has distinct advantages over the other two for interior environments. Primarily, the advantage lies in the fact that the CPS eliminates the requirement for masks and protective clothing to be continually worn inside the protected area as long as the CPS is functioning properly. This eliminates the encumbrance of this equipment and any compatibility problem with equipment to be operated (keyboards, switchboards, telephones, optical equipment, and so forth). Additionally, there is no problem of mask hose interference or reduction of mobility. The advantage of the overpressure system carries over in that the danger of interior compartment contamination is minimized, therefore minimizing the requirement to decontaminate the compartment and its contents. This aspect must not be considered lightly in view that effective decontamination of electronic or optical equipment will be difficult if not impossible in the field, and because of the intimate contact of the personnel with instruments and controls, as well as other interior surfaces of the compartment, contamination of the interior cannot be tolerated. There is the possibility that the CPS will fail or be defeated, meaning that the crew will be required to complete all critical tasks wearing the protective clothing. Therefore, all critical work stations inside the CPS area shall be assigned to be operated and maintained if necessary by personnel wearing the NBC or other protective suits.

32.15.4 Protective Ensemble—Wearing the protective ensemble mask, hood, overgarment, and gloves poses some serious problems in functional efficiency degradation caused by heat stress, loss of visual field (particularly if there is a requirement to use optical equipment), mask lens fogging, reduction of manual dexterity, and an overall degradation in movement caused by the bulk of the protective suit.

32.15.5 Human Factors Implication—Because of the heat buildup in the protective suits, sufficient cooling shall be provided, or the time required for a suit to be worn will be limited so that the environment, delineated in 32.7, shall not be exceeded. Control devices, hand access openings, and so forth, shall be sized in accordance with the dimensions given in Fig. 60, Glove Type B. Limb and LC head movement ranges, wearing an NBC or other protective ensemble, have not been well defined. In lieu of better data, a good design practice is to

<table>
<thead>
<tr>
<th>TABLE 31 Human Reaction to Windchill</th>
<th>Windchill Value</th>
<th>Human Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Warm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 Pleasant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>800 Cold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 Very cold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200 Bitterly cold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1400 Exposed flesh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![FIG. 92 Equivalent Chill Temperature](image)

<table>
<thead>
<tr>
<th>WIND SPEED</th>
<th>COOLING POWER OF WIND EXPRESSED AS &quot;EQUIVALENT CHILL TEMPERATURE&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>M/SEC</td>
<td>TEMPERATURE (°C)</td>
</tr>
<tr>
<td>CALM</td>
<td>4</td>
</tr>
</tbody>
</table>

**WINDS ABOVE 18 M/SEC HAVE LITTLE ADDITIONAL EFFECT**

**LITTLE DANGER** (FLESH MAY FREEZE WITHIN 1 MINUTE)

**ACCEPTABLE** (FLESH MAY FREEZE WITHIN 30 SECS)
<table>
<thead>
<tr>
<th>Work Area or Type of Task</th>
<th>Illumination Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recommended, ft·c (lux)¹</td>
</tr>
<tr>
<td>Assembly, missile component</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>Assembly, general:</td>
<td></td>
</tr>
<tr>
<td>coarse</td>
<td>50 (540)</td>
</tr>
<tr>
<td>medium</td>
<td>75 (810)</td>
</tr>
<tr>
<td>fine</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>precise</td>
<td>300 (3230)</td>
</tr>
<tr>
<td>Bakery</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Bench work:</td>
<td></td>
</tr>
<tr>
<td>rough</td>
<td>50 (540)</td>
</tr>
<tr>
<td>medium</td>
<td>75 (810)</td>
</tr>
<tr>
<td>fine</td>
<td>150 (1615)</td>
</tr>
<tr>
<td>extra fine</td>
<td>300 (3230)</td>
</tr>
<tr>
<td>Business machine operation</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>(calculator, digital, input, and so forth)</td>
<td></td>
</tr>
<tr>
<td>Chemical laboratory</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Console surface</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Corridors</td>
<td>20 (215)</td>
</tr>
<tr>
<td>Circuit diagram</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>Dials</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Electrical equipment testing</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Elevators</td>
<td>30 (325)</td>
</tr>
<tr>
<td>Emergency lighting</td>
<td>3 (30)</td>
</tr>
<tr>
<td>Gages</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Galley</td>
<td>70 (755)</td>
</tr>
<tr>
<td>Hallways</td>
<td>20 (215)</td>
</tr>
<tr>
<td>Inspection tasks, general:</td>
<td></td>
</tr>
<tr>
<td>rough</td>
<td>50 (540)</td>
</tr>
<tr>
<td>medium</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>fine</td>
<td>200 (2155)</td>
</tr>
<tr>
<td>extra fine</td>
<td>300 (3230)</td>
</tr>
<tr>
<td>Laundry:</td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>50 (540)</td>
</tr>
<tr>
<td>spotting</td>
<td>500 (4645)</td>
</tr>
<tr>
<td>hand pressing</td>
<td>150 (1395)</td>
</tr>
<tr>
<td>Machine shop:</td>
<td></td>
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<tr>
<td>general</td>
<td>50 (540)</td>
</tr>
<tr>
<td>fine bench work</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>Medical spaces:</td>
<td></td>
</tr>
<tr>
<td>waiting areas</td>
<td>70 (755)</td>
</tr>
<tr>
<td>labs and examination rooms</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>surgery</td>
<td></td>
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<tr>
<td>Meters</td>
<td>50 (540)</td>
</tr>
<tr>
<td>Missiles:</td>
<td></td>
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<tr>
<td>repair and servicing</td>
<td>100 (1075)</td>
</tr>
<tr>
<td>storage areas</td>
<td>20 (215)</td>
</tr>
<tr>
<td>general inspection</td>
<td>50 (540)</td>
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<tr>
<td>Office work, general</td>
<td>70 (755)</td>
</tr>
<tr>
<td>Ordinary seeing tasks</td>
<td>50 (540)</td>
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<tr>
<td>Paint room:</td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>30 (325)</td>
</tr>
<tr>
<td>color matching</td>
<td></td>
</tr>
<tr>
<td>Panels:</td>
<td></td>
</tr>
<tr>
<td>front</td>
<td>50 (540)</td>
</tr>
<tr>
<td>rear</td>
<td>30 (325)</td>
</tr>
<tr>
<td>Passageways</td>
<td>20 (215)</td>
</tr>
<tr>
<td>Reading:</td>
<td></td>
</tr>
<tr>
<td>large print</td>
<td>30 (325)</td>
</tr>
<tr>
<td>newsprint</td>
<td>50 (540)</td>
</tr>
<tr>
<td>handwritten reports, in pencil</td>
<td>70 (755)</td>
</tr>
<tr>
<td>small type</td>
<td>70 (755)</td>
</tr>
<tr>
<td>prolonged reading</td>
<td>70 (755)</td>
</tr>
<tr>
<td>Recording</td>
<td>70 (755)</td>
</tr>
<tr>
<td>Repair work:</td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>50 (540)</td>
</tr>
<tr>
<td>instrument</td>
<td>200 (2155)</td>
</tr>
<tr>
<td>Sanitary spaces:</td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>30 (325)</td>
</tr>
</tbody>
</table>
place all controls and displays within the normal equipment operation lower limits shown in Fig. 69. As for the anthropometric dimensions of the human body in an NBC or other ensemble, use the dimensions shown in Figs. 53-58 and Table 22 for the arctic-clothed person as a best estimation of the effect of an NBC or other ensemble on the body dimensions for both static and dynamic situations.

33. Maintainability

33.1 General:

33.1.1 Standardization—Standard parts shall be used whenever practicable and shall meet the human engineering criteria herein.

33.1.2 Special Tools—Special tools shall be used only when common hand tools cannot be used or when they provide significant advantage over common hand tools. Special tools required for operational adjustment maintenance shall be securely mounted within the equipment in a readily accessible location.

33.1.3 Modular Replacement—Equipment shall be replaceable as modular packages and shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations (see 38.3).

33.1.4 Separate Adjustability—It shall be possible to check and adjust each item, or function of an item, individually.

33.1.5 Malfunction Identification—Equipment design shall facilitate rapid and positive fault detection and isolation of defective items to permit their prompt removal and replacement.

33.1.6 Assembly and Disassembly—Equipment shall be capable of being assembled and disassembled in its operational environment by a minimum number of trained personnel wearing clothing appropriate to the operating environment specified for the system maintenance concept.

33.1.7 Clothing Constraints—Equipment shall be capable of being removed, replaced, and repaired by personnel wearing personal and special purpose clothing and equipment appropriate to the maintenance concept, including NBC protective clothing in an NBC-contaminated environment.

33.1.8 Errorproof Design—Provisions to preclude improper mounting and installation shall include:

33.1.8.1 Physical measures to preclude interchange of items of a same or similar form that are not in fact functionally interchangeable.

---

**TABLE 32 Continued**

<table>
<thead>
<tr>
<th>Work Area or Type of Task</th>
<th>Illumination Levels</th>
<th>Recommended, ft·c (lux)$^a$</th>
<th>Minimum, ft·c (lux)$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scales</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>Screw fastening</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>Service areas, general</td>
<td>20 (215)</td>
<td>10 (110)</td>
<td></td>
</tr>
<tr>
<td>Sheet metal works:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>scribbling</td>
<td>200 (2155)</td>
<td>100 (1075)</td>
<td></td>
</tr>
<tr>
<td>Ship stores:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aisles</td>
<td>30 (325)</td>
<td>10 (110)</td>
<td></td>
</tr>
<tr>
<td>Stairways</td>
<td>20 (215)</td>
<td>10 (110)</td>
<td></td>
</tr>
<tr>
<td>Storage:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inactive or dead</td>
<td>5 (55)</td>
<td>3 (30)</td>
<td></td>
</tr>
<tr>
<td>general warehouse</td>
<td>10 (110)</td>
<td>5 (55)</td>
<td></td>
</tr>
<tr>
<td>live, rough or bulk</td>
<td>10 (110)</td>
<td>5 (55)</td>
<td></td>
</tr>
<tr>
<td>live, medium</td>
<td>30 (315)</td>
<td>20 (215)</td>
<td></td>
</tr>
<tr>
<td>live, fine</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>Switchboards</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>Tanks, containers</td>
<td>20 (215)</td>
<td>10 (110)</td>
<td></td>
</tr>
<tr>
<td>Testing:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rough</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>fine</td>
<td>100 (1075)</td>
<td>50 (540)</td>
<td></td>
</tr>
<tr>
<td>extra fine</td>
<td>200 (2155)</td>
<td>100 (1075)</td>
<td></td>
</tr>
<tr>
<td>Transcribing and tabulation</td>
<td>100 (1075)</td>
<td>50 (540)</td>
<td></td>
</tr>
<tr>
<td>Welding:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>50 (540)</td>
<td>30 (325)</td>
<td></td>
</tr>
<tr>
<td>precision arc</td>
<td>1000 (10 765)</td>
<td>500 (540)</td>
<td></td>
</tr>
<tr>
<td>Woodworking:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>general</td>
<td>30 (325)</td>
<td>100 (1075)</td>
<td></td>
</tr>
</tbody>
</table>

$^a$As measured at the task object or 760 mm (30 in.) above the floor.
33.1.8.2 Physical measures to preclude improper mounting of units or components.

33.1.8.3 Measures (for example, coding) to facilitate identification and interchange of interchangeable items.

33.1.8.4 Measures (for example, alignment pins) to facilitate proper mounting of items.

33.1.8.5 Measures to insure that identification, orientation, and alignment provisions include cables and connectors.

33.1.8.6 Provide for controls and displays that give the status of equipment indicating when maintenance must be preformed (for example, AP meter on strainer) and locate them so it is obvious which equipment they are associated with.

33.2 Designing for Maintainability—Designers shall incorporate the following features for maximum maintainability:

### TABLE 33 Recommendations for Display Lighting

<table>
<thead>
<tr>
<th>Condition of Use</th>
<th>Lighting Technique&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Brightness of Markings cd/m&lt;sup&gt;2&lt;/sup&gt; (Ft-L)</th>
<th>Brightness Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator reading, dark adaptation necessary</td>
<td>red flood, indirect, or both, with operator choice</td>
<td>0.07–0.35 (0.02–0.1)</td>
<td>cont. throughout range</td>
</tr>
<tr>
<td>Indicator reading, dark adaptation not necessary but desirable</td>
<td>red or low-color temperature white flood, indirect, or both, with operator choice</td>
<td>0.07–3.5 (0.02–1.0)</td>
<td>cont. throughout range</td>
</tr>
<tr>
<td>Indicator reading, dark adaptation not necessary</td>
<td>white flood</td>
<td>3.5–70 (1–20)</td>
<td>fixed or continuous</td>
</tr>
<tr>
<td>Panel monitoring, dark adaptation necessary</td>
<td>red edge lighting, red or white flood, or both, with operator choice</td>
<td>35–70 (10–20)</td>
<td>cont. throughout range</td>
</tr>
<tr>
<td>Panel monitoring, dark adaptation not necessary</td>
<td>white flood</td>
<td>35–70 (10–20)</td>
<td>fixed or continuous</td>
</tr>
<tr>
<td>Possible exposure to bright flashes, restricted daylight</td>
<td>white flood</td>
<td>35–70 (10–20)</td>
<td>fixed</td>
</tr>
<tr>
<td>Chart reading, dark adaptation necessary</td>
<td>red or white flood with operator choice</td>
<td>0.35–3.50 (0.1–1.0)</td>
<td>cont. throughout range</td>
</tr>
<tr>
<td>Chart reading, dark adaptation necessary</td>
<td>white flood</td>
<td>17–70 (5–20)</td>
<td>fixed or continuous</td>
</tr>
</tbody>
</table>

<sup>a</sup>Where detection of a ground vehicles or other protected assets by image intensifier night vision devices must be minimized, blue-green light (incandescent filament through a filter which passes only wave lengths shorter than 600 nm) should be used in lieu of red light.

### TABLE 34 Low-Frequency and Infrasonic Noise Limits to Prevent Ear Injury

<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>SPL, dB</th>
<th>Duration, min/day</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–7</td>
<td>150</td>
<td>4</td>
<td>Should use earplugs to reduce unpleasant sensations</td>
</tr>
<tr>
<td>8–11</td>
<td>145</td>
<td>4</td>
<td>Should use earplugs to reduce unpleasant sensations</td>
</tr>
<tr>
<td>12–20</td>
<td>140</td>
<td>4</td>
<td>Should use earplugs to reduce unpleasant sensations</td>
</tr>
<tr>
<td>21–100</td>
<td>135</td>
<td>20</td>
<td>Without earplugs</td>
</tr>
<tr>
<td>21–100</td>
<td>150</td>
<td>20</td>
<td>With earplugs</td>
</tr>
</tbody>
</table>

33.2.1 Simplification of operator and maintenance functions.
33.2.2 Use of modular or unit packaging or throwaway components designed for rapid and easy removal and replacement by one person (if feasible) with the weight limitations contained in Table 43 in 38.3.1.

33.2.3 Use of self-lubricating principles.

33.2.4 Use of sealed and lubricated components and assemblies.

33.2.5 Use of built-in testing and calibration features for major components.

33.2.6 Use of self-adjusting mechanisms.

33.2.7 Use of gear-driven accessories to eliminate belts and pulleys.

33.2.8 Minimum number and complexity of maintenance tasks.

33.2.9 Design to minimize skills and training requirements of maintenance personnel.

33.2.10 Design for accessibility to all systems, equipment, and components requiring maintenance, inspection, removal, and replacement.

33.2.11 Design for maximum safety and protection for personnel and equipment.

33.2.12 Design to incorporate standard parts to the maximum extent feasible.

33.2.13 Design to facilitate manual handling required during maintenance and comply with established manual force criteria.

33.2.14 Design so inputs to and outputs from each unit shall be kept to a minimum by grouping functions to minimize criss-crossing of signals.

33.3 Mounting of Items Within Units:

33.3.1 Stacking Avoidance—Parts shall be mounted in an orderly array on a “two-dimensional” surface, rather than stacked one on another (that is, a lower layer shall not support an upper layer, so subassemblies do not have to be removed to access other subassemblies within the equipment).

33.3.2 Similar Items—Similar items shall use a common mounting design and orientation within the unit. This mounting design shall preclude interchange of items that are not functionally interchangeable. Similar items that are not functionally interchangeable shall be made distinguishable by labeling, color coding, marking, and so forth, to prevent unwanted substitution.

33.3.3 Delicate Items—Components susceptible to maintenance-induced damage through rough handling, static electricity, abrasion, lack of cleanliness, or other such factors shall be clearly identified and guarded from abuse both physically and by procedural requirements.

33.4 Adjustment Controls—Controls required for maintenance purposes shall comply with basic control design requirements in Sections 23, 24, and 25 and labeling requirements in Section 27.

33.4.1 Knob Adjustments—Knobs rather than screwdriver controls shall be used whenever adjustments occurring more often than once per month must be performed where access, weight, and related considerations permit their use. Knobs shall maintain setting following adjustment.

33.4.2 Blind Screwdriver Adjustments—Screwdriver adjustments made without visual access are permissible only if mechanical guides are provided to align the screwdriver. Screw travel shall be limited to prevent the screw from falling out of its intended position.

33.4.3 Reference Scale for Adjustment Control—A reference scale or other appropriate feedback shall be provided for all adjustment controls. The reference scale shall be readily visible to the person making the adjustment. Mirrors or flashlights shall not be required for adjustment.

33.4.4 Control Limits—Calibration or adjustment controls that are intended to have a limited degree of motion shall have mechanical stops with strength to prevent damage by a force or torque 100 times greater than the resistance to movement within the range of adjustment.

33.4.5 Critical Controls—Critical and sensitive adjustment controls shall incorporate features to prevent inadvertent or accidental actuation. If a locking device is to be used to prevent inadvertent or accidental actuation, operation of the locking device shall not change the adjustment setting. Where the operator or maintainer is subjected to disturbing vibrations or acceleration during the adjustment operation, suitable hand or arm support shall be provided near the control location to facilitate making adjustment.

33.4.6 Hazardous Locations—Adjustment controls shall not be located close to dangerous voltages, moving machinery, or any other hazards. If such location cannot be avoided, the controls shall be appropriately shielded and labeled.
33.5 Environment:

### TABLE 38 Effects of Noise on Human Performance

<table>
<thead>
<tr>
<th>Noise Level, dB</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Serious reduction in alertness. Attention lapses occur, although attention duration is usually not affected. Temporary hearing loss occurs if no protection is provided in the region 600 to 1200 Hz. Most people will consider this level unacceptable, and 8 h is the maximum duration they will accept.</td>
</tr>
<tr>
<td>95</td>
<td>Considered to be upper acceptance level for occupied areas in which people expect the environment to be noisy. Temporary hearing loss often occurs in the range from 300 to 1200 Hz. Speech will be extremely difficult, and people will be required to shout, even though they may be talking directly into a listener’s ear.</td>
</tr>
<tr>
<td>90</td>
<td>At least half of the people in any given group will judge the environment as being too noisy, even though they expected a noisy environment. Some temporary hearing loss in the range from 300 to 1200 Hz occurs. Skill errors and mental decrements will be frequent. The annoyance factor is high, and certain physiological changes often occur (for example, the pupils dilate, the blood pressure increases, and the stroke volume of the heart may decrease). Listening to a radio is impossible without good earphones. The maximum duration that most people will accept is 8 h.</td>
</tr>
<tr>
<td>85</td>
<td>The upper acceptance level (noise expected) in the range from 150 to 1200 Hz. Some hearing loss occurs in the range from 300 to 1200 Hz. This is considered the upper comfort level, although some cognitive performance decrement can be expected, especially where decision making is necessary.</td>
</tr>
<tr>
<td>80</td>
<td>Conversation is difficult (that is, people have to converse in a loud voice less than 1 ft apart). It is difficult to think clearly after about 1 h. There may be some stomach contraction and an increase in metabolic rate. Strong complaints can be expected from those exposed to this level in confined spaces, and 8 h is the maximum duration acceptable within the frequency range from 1200 to 4800 Hz.</td>
</tr>
<tr>
<td>75</td>
<td>Too noisy for adequate telephone conversation. A raised voice is required for conversant 0.68 cm (2 ft) apart. Most people will still judge the environment as being too noisy.</td>
</tr>
<tr>
<td>70</td>
<td>The upper level for the normal conversation, even when conversants are close together (at a distance of 1.8 m (6 ft)) people will have persons such as industrial workers and shipboard personnel who are used to working in a noisy environment will accept this noise level, unprotected telephone conversation will be difficult (upper phone level is 68 dB). The acceptance level when people expect a generally noisy environment. Intermittent personal conversation is acceptable. About half of the people in a given population will experience difficulty sleeping.</td>
</tr>
<tr>
<td>65</td>
<td>The upper limit for spaces used for dining, social conversation, and sedentary recreational activities. Most people will rate the environment as “good” for general daytime living conditions.</td>
</tr>
<tr>
<td>60</td>
<td>The upper acceptance level for spaces in which quiet is expected (150 to 2400 Hz). People will have to raise their voices slightly to converse over distances greater than 2.4 m (8 ft). This level of noise will awaken about half of a given population about half of the time. It is still annoying to people who are especially sensitive to noise.</td>
</tr>
<tr>
<td>55</td>
<td>Acceptable to most people where quiet is expected. About 25% will be awakened or delayed in falling asleep. Normal conversation is possible at distances up to 2.4 m (8 ft).</td>
</tr>
<tr>
<td>50</td>
<td>Very acceptable to all. The recommended upper level for quiet living spaces, although a few people may still have sleep problems.</td>
</tr>
<tr>
<td>Below 30</td>
<td>Introduces additional problems: low-level intermittent sounds become disturbing. Some people have difficulty getting used to the extreme quiet, and a few may become psychologically disturbed.</td>
</tr>
</tbody>
</table>
### TABLE 39 Effects of High-Level Noise on Human Performance

<table>
<thead>
<tr>
<th>Noise Level, dB</th>
<th>Spectrum</th>
<th>Duration</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>Jet engine</td>
<td>2 min</td>
<td>Reduced visual acuity, stereoscopic acuity, and near point accommodation and permanent hearing loss when exposure continue over a long period of (months)</td>
</tr>
<tr>
<td>110</td>
<td>Machinery noise</td>
<td>8 h</td>
<td>Chronic fatigue and digestive disorders</td>
</tr>
<tr>
<td>120</td>
<td>Broadband</td>
<td>1 h</td>
<td>Loss of equilibrium</td>
</tr>
<tr>
<td>150</td>
<td>1–100 Hz</td>
<td>2 min</td>
<td>Reduced visual acuity, chest-wall vibration, changes in respiratory rhythm, and a “gagging” sensation</td>
</tr>
</tbody>
</table>

**33.5.1 Heat**—When monitoring, servicing, repair, or other similar maintenance tasks will be performed in areas in which the temperature will exceed 29.5°C (85°F), air conditioning shall be provided. For additional information on the effect of heat on human performance and behavior see 32.2.

**33.5.2 Cold**—Personal discomfort increases rapidly as the temperature drops below −12°C (10°F). When workers are properly dressed, they can perform to some point between 0 and −18°C (32 and 0°F) for 30 min without interference from cold itself. Below −18°C (0°F), the decrement in human performance rapidly increases as the temperature decreases. For additional information on the effects of cold temperatures on human performance see Tables 29-31.

**33.5.3 Design Features**—The following features shall be considered when equipment can be expected to require maintenance in cold weather.

- **33.5.3.1** Provide for drying of equipment which is to be returned to out-of-door arctic temperatures after shop maintenance has been performed on it. Moisture that has condensed on such equipment will cause it to freeze with possible resultant damage to equipment and subsequent increased maintenance.

- **33.5.3.2** Winterization equipment, such as preheaters, shall be positioned where they do not interfere with maintenance accessibility to perform maintenance tasks.

- **33.5.3.3** In locating access doors and panels, consider the effects of rain, snow, and formation of ice.

- **33.5.3.4** Provide work space access openings to accommodate personnel wearing cold weather clothing.

- **33.5.3.5** Provide drains that can be adequately accessed and operated by personnel wearing cold weather clothing to drain liquids as required to prevent damage caused by freezing.

**33.6 Mounting of Items Within Units.**

### 34. Accessibility

**34.1 General**—Proper accessibility is a fundamental requirement for good maintainability, and must be designed into the equipment and overall system. Accessibility means that all activities required can be completed by personnel using the appropriate body dimensions (see Section 30, Anthropometry), fifth to ninety-fifth percentile, wearing the appropriate clothing and carrying (or using) all necessary tools or test equipment, or both. Just because an item can be eventually reached (provided enough other items are removed, or valve handles or lagged piping has to be used as a “step ladder,” and so forth) does not mean the item is accessible.

**34.2 Psychological Aspects**—The more difficult or involved a maintenance task is, the more readily an operator or mechanic will put it off in preference to less demanding tasks. Periodic maintenance activities, such as checks, adjustments, or general troubleshooting may be unduly postponed or neglected entirely.

**34.3 Physical Access**—Consideration must be given to the position of the maintenance person with respect to the equipment and the task therein while performing the particular maintenance task. When the maintenance activities require the crew member to squat, sit down, stand sideways, proper accessibility shall be provided (see Figs. 99-103).

**34.4 Access Openings**—Provide access openings, as required, to all points, items, units, and components that require testing, servicing, adjusting, removing, replacing, and repairing. The type, size, and location of these openings (Figs. 104-106) shall be based on the following:

- **34.4.1** Operational location, setting, and environment of the unit.

- **34.4.2** Frequency of use.

- **34.4.3** Maintenance tasks performed through the access; the intricacy of tasks.

- **34.4.4** Time allotted to perform maintenance function.

- **34.4.5** Types of tools/accessories required.

- **34.4.6** Work space required.

- **34.4.7** Type of clothing the maintainer is likely to be wearing.

- **34.4.8** Necessary access reach (position of the human body; standing, squatting, lying prone, and so forth, must be considered in determining access reach).

- **34.4.9** Visual requirements; the intricacy of tasks.

**34.5 Visual Access with Physical Access**—If it is necessary for the technicians to see what they are doing, either access openings large enough to accommodate hand, arms, tools, and so forth, and still leave an adequate view, or an auxiliary viewing port shall be provided.

**34.6 Structural Members**—Structural members of units or chassis shall not prevent access to or removal of items. Replaceable items shall not be mounted in a manner that will make them difficult to remove. Where accessibility depends upon removal of panels, cases, and covers, measures shall be taken to ensure that such items are not blocked by structural members or other items.

**34.7 Large Items**—Large items that are difficult to remove shall be so mounted that they will not prevent convenient access to other items. Smaller, or more fragile, items shall be located so as not to be easily damaged during removal of the large items.

**34.8 Use of Tools and Test Equipment**—Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

**34.9 Rear Access**—Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate their full distance and remain in the open position without
being supported by hand. Rear access shall also be provided to plug connectors for test points, soldering, and pin removal where connectors require such operations.

34.10 Relative Accessibility—Items most critical to system operation and which require rapid maintenance shall be most accessible. When relative criticality is not a factor, items requiring most frequent access shall be most accessible.

34.11 High-Failure-Rate-Items—High-failure-rate items shall be accessible for replacement without moving nonfailed items. Mechanical replacement items shall be removable with common hand tools and simple handling equipment.

34.12 Skills—Access to items maintained by one technician shall not require removal of critical equipment maintained by another technician, particularly where highly specialized skills are involved.

34.13 Moving Parts—Maintenance tasks shall not be required on items for which the human must lean over or work directly around moving parts (belts, elevator cables, rotating shafts, and so forth), especially if it is necessary to have the moving parts active as a part of the maintenance procedure.

34.14 Elevated Positions—Items to be maintained from a ladder shall require only one hand and shall be located no more than 1219 mm (48 in.) from the ladder (see Fig. 40). Maintenance tasks performed at this maximum distance shall involve only adjustments or other similar tasks that can be performed with the bare hand or light tools.

34.15 Masts—Maintenance on antenna, lights, and so forth, mounted on a mast or other elevated structure, shall not require the person to be suspended from a safety harness, but rather shall be performed from a permanent or temporary work platform.

34.16 Strainers and Filters—Strainers and filters shall be located so that the person does not have to stand on valve handles, piping, wireway supports, and so forth to obtain access to the elements inside for removal for cleaning.

34.17 Rechargeable Containers—Compressed gas bottles for inert gases (nitrogen flasks in oil and water test labs), fire-extinguishing materials, and so forth, shall be located in a compartment or space to facilitate easy and quick removal.

34.18 Access Opening Covers—Where an access opening is provided the order of preference, as shown in Fig. 106, shall be followed regarding the provision of an access cover.

34.18.1 Securing of Covers—It shall be made obvious when a cover is not secured even though it may be in place.

34.18.2 Self-Supporting Covers—Hinged access covers that are not completely removable shall be self-supporting in the
open position. The cover in the open position shall not obstruct required visual or physical access to the equipment being maintained or to related equipment during maintenance. Self-supporting covers shall be capable of being opened and closed.

FIG. 97 Vibration Exposure Criteria for Longitudinal (Upper Figure) and Transverse (Lower Figure) Directions with Respect to Body Axis

NOTE: Exposure limits are presented as a function of frequency (pure sinusoidal vibration or Rms vibration values in third octave bands) with exposure time as a parameter.
with one hand. Covers shall be secured to withstand wind gusts, vibrations, or other environmental effects as specified by system requirements.

34.18.3 Instructions—If the method of opening a cover is not obvious from the construction of the cover itself, instructions shall be permanently displayed on the outside of the cover. Instructions shall consist of simple symbols such as arrows or simple words such as “push” or “push and turn.”

34.18.4 Clearance—Bulkheads, brackets, and other equipment shall not obstruct visual or physical access for removal or opening of covers on equipment within which work must be performed in the installed condition. Covers, doors, or panels that must be opened to perform onsite maintenance shall be visually and physically accessible to the maintainers.

34.18.5 Labeling—Each access cover shall be labeled with nomenclature for items visible or accessible through it, nomenclature for auxiliary equipment to be used with it, and recommended procedures for accomplishing operations. Accesses shall be labeled with hazard signs advising of any hazards existing beyond the access. If instructions applying to a covered item are lettered on a hinged door, the lettering shall be properly oriented to be read when the door is open. Hazard notices shall be prepared in accordance with 29.2.

34.18.6 Access Cover Attachment—Covers shall be attached with the fewest number of simplest-to-operate fasteners practicable. Fasteners shall be operable by hand or by common hand tools in that order of preference. Small, removable covers shall be attached to structure or otherwise retained to prevent loss.

34.19 Rounding—Cover and access edges shall be rounded (see 51.7.4, Edge Rounding) to preclude hand injury or clothing damage.

34.20 Operation—Access covers shall be equipped with grasp areas or other means for opening them. If a hazardous condition, such as exposed conductors energized with dangerous voltages exists behind the access, the physical barrier over the access shall be equipped with an interlock that will deenergize the hazardous equipment when the barrier is opened or removed. Bulkheads, brackets, wireways, and other equipment shall not interfere with the removal or opening of covers, or restrict access to these openings, or interfere with the maintenance tasks that must be performed through the openings. Additional design criteria are as follows:

34.20.1 When hinged covers are adjacent, they shall open in the opposite directions to maximize accessibility.

34.20.2 Design hinged caps over service or test points so they will not interfere with inserting or attaching service or test equipment.

34.20.3 Use stops, retainers, and so forth, as necessary to keep covers from swinging into adjacent controls or fragile components, and so they will not spring their hinges.
34.20.4 Sliding covers or caps are particularly useful where swinging space is limited. Small sliding caps are useful for small accesses that do not require a tight seal. When sliding covers are used, the following shall be considered:

34.20.4.1 Sliding doors and caps shall lock positively.
34.20.4.2 They shall be designed so that they will not jam or stick.
34.20.4.3 They shall be easy to use, and personnel shall be able to use them without tools and with heavy gloves.

34.21 Removable covers, plates, or caps require little space for opening and, once removed, do not interfere with work space. However, handling them takes time and effort. When using removable covers, consider the following:

34.21.1 Use tongue-and-slot or similar catches wherever possible for small covers and caps to minimize the number of fasteners required.
34.21.1.1 If small covers and caps are likely to be misplaced or damaged, secure them with retainer chains.
34.21.1.2 If a removable cover must be attached in a certain way, design it so it cannot be attached improperly (use an asymmetric shape, locate mounting holes asymmetrically, or code both cover and structure with labels that will align when the plate is properly installed).

34.22 Location of Access Covers—Accesses shall be located only on equipment surfaces that are directly accessible when normally installed.

34.23 Physical Access:

34.23.1 Arm and Hand Access—Access openings provided for adjusting and handling interior equipment shall be sized to permit the required operations and shall provide an adequate view of the item being manipulated. All blind arm and hand access shall require approval of procuring authority.

34.23.2 Opening Covers—Access covers shall be equipped with grasp areas or other means for opening them. Where operations will require opening and closing the covers while wearing gloves or special clothing, opening provision shall accommodate the gloves or special clothing.

34.23.3 Reach Access Dimensions—The dimensions of access openings for arms, hands, and fingers shall be no less than those shown in Figs. 99-105. Allowance shall be made for the clearance of the operator’s gloved or mitten hand or special clothing as appropriate. Shape of access shall allow easy passage of equipment, body appendage, or tools as appropriate. Access shape shall permit passage of all equipment that must be replaced through the opening allowing for protuberances, attachments, and handles on the equipment.

34.23.4 Tool Access Dimensions—Access openings shall be large enough to operate tools required for maintenance of the equipment reached through the access.

34.23.5 Remove and Replace Dimensions—Opening size for removal and replacement of equipment shall allow for handling clearance for bare hand or gloved hand as appropriate.

34.23.6 Guarding Hazardous Conditions—If a hazardous condition, such as exposed conductors energized with dangerous voltages or currents, exist behind the access, the physical barrier over the access shall be equipped with an interlock that will deenergize the hazardous equipment when the barrier is open or removed. Both the presence of the hazard and the fact that an interlock exists shall be noted on the equipment case or cover such that it remains visible when the access is open.

34.23.7 Type of Opening—Where physical access is required, the following practices shall be followed in order of preference:

34.23.7.1 An opening with no cover unless this is likely to degrade system performance, safety, or NBC contamination survivability.

34.23.7.2 A hand-operated (latched, sliding, or hinged) cap or door where dirt, moisture, or other foreign materials might otherwise create a problem.

34.23.7.3 A quick-opening cover plate using 1/4-turn captive fasteners if a cap will not meet stress requirements or space prevents a hinged cover.

34.23.7.4 When captive fasteners cannot be used because of stress, structure, or pressurization, screw down cover. Use minimum number of interchangeable screws to fasten door.

34.24 Visual Access—Where visual access is required, the opening shall provide a visual angle sufficient to view all required information at the normal operating or maintenance position. The maintainer shall be provided unrestricted visual access from the work station without bending. Where bending is required, frequency and time in the bent position shall not cause fatigue. Where visual access only is required, the following practices shall be followed in order of precedence:

34.24.1 An opening with no cover except where this might degrade system performance or NBC survivability.

34.24.2 A transparent window if dirt, moisture, or other foreign materials might otherwise create a problem.

34.24.3 A break-resistant glass window if physical wear, heat, or contact with solvents would otherwise cause optical deterioration.

34.24.4 A quick-opening metal cover if glass will not meet stress or other requirements.

35. Cases

35.1 Orientation—The proper orientation of an item within its case shall be made obvious, either through design of the case or by means of appropriate labels.

35.2 Removal—When practical, cases shall be designed to be lifted from items rather than items lifted from cases (see Fig. 107). Equipment shall be protected from damage when cases are removed or replaced; cases shall not require manual support to remain in the open position during maintenance.
35.3 **Size**—Cases shall be sufficiently larger than the items they cover to minimize the possibility of damaging wires or other parts when the cases are put on or taken off.

35.4 **Guides**—Guides, tracks, and stops shall be provided as necessary to help align the case to prevent damage to equipment or injury to personnel.

35.5 **Weight**—They shall be removable and transportable by one hand, by one person, or by two persons, in that order of preference.

35.6 **Handles**—Handles or tool grips, in accordance with 38.5, shall be provided if the case is heavy, difficult to open, or difficult to handle.

36. **Lubrication**

36.1 **General**—Configuration of equipment containing mechanical items requiring lubrication shall permit both lubrication and checking of lubricant levels without disassembly.
Where fittings are not directly accessible (for example, around steering gear stocks and around inside vertical package conveyors, and so forth), these fittings shall be extended via tubing to a location where they are directly accessible. Permanently lubricated items for which lubricant lasts for the life of the items are excluded.

36.2 Labeling—Where lubrication is required, the type of lubricant to be used and the frequency of lubrication may be specified via a lubrication chart of permanent construction mounted at or near the lube port or at the operator station of the equipment. A lubrication chart of permanent construction shall be mounted at the operator station of the equipment; lubrication charts or individual labels shall not be required when the equipment has only one type of fitting and uses only one type of lubricant.

37. Fasteners

37.1 General—The number and diversity of fasteners used shall be minimized commensurate with stress, bonding, pressurization, shielding, thermal, and safety requirements. Finger- or hand-operated fasteners shall be used when consistent with these requirements, except where screws with heads flush with the case or fastening surface are required for NBC survivability. Fasteners requiring nonstandard tools shall not be used. Fasteners used on items requiring use by NBC-suited personnel shall be quick acting, with no sharp edges or protrusions that could puncture or tear the NBC suit.

37.2 Hinges and Tongue-and-Slot Catches—Optimum use shall be made of hinges and tongue-and-slot catches to minimize the number of fasteners required.

37.2.1 Captive Fasteners—Captive fasteners shall be used where dropping or loss of such items could cause damage to equipment or create a difficult or hazardous removal problem. Captive fasteners shall also be provided for access covers requiring frequent removal.

37.2.2 Quantity—If a hinged access panel or quick-opening fasteners will not meet stress, pressurization, shielding, or safety requirements, the minimum number consistent with these requirements shall be used.

37.2.3 Fastener Head Type:

37.3 High-Torque Fasteners—External hex or external double-hex wrenching elements shall be provided on all machine screws, bolts, or other fasteners requiring more than 14 N·m (10 ft·lb) of torque. When external wrenching fasteners cannot meet the mechanical function or personnel safety requirements, or in limited access situations, and where use is protected from accumulation of foreign material, internal wrenching fasteners may be used.

37.4 Low-Torque Fasteners—Hex-type internal grip head, hex-type external grip head, or combination head (hex or straight-slot internal grip and hex-type external-grip head), or torque-set fasteners shall be provided where less than 14 N·m (10 ft·lb) torque is required; however, internal-grip head fasteners shall be provided only where a straight or convex smooth surface is required for mechanical function or for personnel safety and where use is protected from accumulation of foreign material (such as ice or snow). Straight-slot or Phillips-type internal grip fasteners shall not be provided except as wood fasteners or where these type fasteners are provided on standard commercial items.

37.5 Common Fasteners—Identical screw and bolt heads shall be provided to allow various panels and components to be removed with one type of tool. Combination bolt heads such as the slotted hex head shall be selected whenever feasible.

37.6 Accessibility—The heads of mounting bolts and fasteners shall be located on surfaces directly accessible to the technician.

37.7 Number of Turns—Fasteners for mounting assemblies and subassemblies shall require only one complete turn,
provided that stress, alignment, positioning, and load considerations are not compromised. When machine screws or bolts are required, the number of turns and the amount of torque shall be no more than necessary to provide the required strength except when a common fastener is used.

37.8 Torque Labeling—When fastener torqueing to meet EMI/RFI shielding, thermal conductance, or other constraints is required for organizational or intermediate-level maintenance actions, an instructional label or placard shall be provided in reasonable proximity to fasteners. Labels shall comply with requirements of Section 28.

37.9 Types of Fasteners (In Order of Preference):

37.9.1 Quick Connect-Disconnect Devices—These devices are fast and easy to use, do not require tools, may be operated with one hand, and are very good for securing plug-in components, small components, and covers. However, their power is low, and they cannot be used where a smooth surface is required. The following factors shall be considered in selecting quick connect-disconnect fasteners:

37.9.1.1 Use these fasteners wherever possible when components must be dismantled or removed frequently.

37.9.1.2 These fasteners must fasten and release easily, without requiring tools.

37.9.1.3 They shall fasten or unfasten with a single motion of the hand.

37.9.1.4 It shall be obvious when they are not correctly engaged.

37.9.1.5 When there are many of these fasteners, prevent misconnections by giving the female section a color or shape code, location, or size so it will be attached only to the correct male section.

37.9.2 Latches and Catches—These items are very fast and easy to use, do not require tools, and have good holding power; especially good for large units, panels, covers, and cases. They cannot be used where a smooth surface is required. The following factors shall be considered in selecting quick connect-disconnect fasteners:

37.9.2.1 Use long-latch catches to minimize inadvertent releasing of the latch.

37.9.2.2 Spring-load catches so they lock on contact, rather than requiring positive locking.

37.9.2.3 If the latch has a handle, locate the latch release on or near the handle so it can be operated with one hand.

37.9.2.4 Evaluate latches/catches for snap down/release forces that could be hazardous to hand during operation.

37.9.3 Captive Fasteners—Captive fasteners are slower and more difficult to use, depending upon type, and usually require using common hand tools; but they stay in place, saving time that would otherwise be wasted handling and looking for bolts and screws; can be operated with one hand. The following factors shall be considered in selecting captive fasteners:

37.9.3.1 Use captive fasteners when lost screws, bolts, or nuts might cause a malfunction or excessive maintenance time.

37.9.3.2 Use fasteners that can be operated by hand or with a common hand tool.

37.9.3.3 Use fasteners that can be replaced easily if they are damaged.

37.9.3.4 Captive fasteners of the quarter-turn style shall be self-locking and spring-loaded.

37.9.4 Regular Screws—Round, square, or flat-head screws take longer to use and are subject to loss, damage, stripping, and misapplication. Square-head screws are generally preferable to round or flat ones; they provide better tool contact, have sturdier slots, and can be removed with wrenches. If personnel must drive screws blindly, provide a guide in the assembly to help keep the screwdriver positioned properly. The following factors shall be considered in the selection of screws:

37.9.4.1 Screw heads shall have deep slots that will resist damage.

37.9.4.2 Use screws only when personnel can use screwdrivers in a straight-in fashion; do not require personnel to use offset screwdrivers.

37.9.5 Bolts and Nuts—Bolts are usually slow and difficult to use. Personnel must have access to both ends of the bolt, use both hands, and often use two tools. Also, starting nuts require precise movements. There are many loose parts to handle and lose (nuts, washers, and so forth). Design considerations shall include the following:

37.9.5.1 Keep bolts as short as possible, so they will not snag personnel or equipment.

37.9.5.2 Coarse threads are preferable to fine threads for low torques and reduce the possibility of cross threading.

37.9.5.3 Avoid left-hand threads unless system requirements demand them; then identify both bolts and nuts clearly by marking, shape, or color coding.

37.9.5.4 Use wing nuts (preferably) or knurled nuts for low-torque applications, because they do not require tools.

37.9.6 Combination-Head Bolts and Screws—Combination-head bolts and screws are preferable to other screws or bolts, because they can be operated with either a wrench or a screwdriver, whichever is more convenient, and there is less danger of damaged slots and stuck fasteners. In general, slotted hexagon heads are preferable to slotted knurled heads.

37.9.7 Internal-Wrenching Screws and Bolts—Internal-wrenching screws and bolts (socket heads) allow higher torque, better tool grip, and less wrenching space; but they require special tools, are easily damaged, and are difficult to remove if damaged. They also become filled with ice and frozen mud. The following factors shall be considered in selecting internal-wrenching fasteners:

37.9.7.1 Minimize the number of different sizes to minimize the number of special tools; preferably, use only one size.

37.9.7.2 Select fasteners with deep slots to reduce the danger of damaged fasteners.

37.9.8 Rivets—Rivets are very hard and time-consuming to remove. They shall not be used on any part that may require removal.

37.9.9 Cotter Key—Cotter key users shall consider the following:

37.9.9.1 Keys and pins shall fit snugly, but they shall not have to be driven in or out.

37.9.9.2 Cotter keys shall have large heads for easy removal.

37.9.10 Safety Wire:
37.9.10.1 Use safety wire only where self-locking fasteners cannot withstand the expected vibration or stress.
37.9.10.2 Attach safety wire so it is easy to remove and replace.
37.9.11 Retainer Ring:
37.9.11.1 Avoid rings that become difficult to remove and replace when they are worn.
37.9.11.2 Use rings that hold with a positive snap action when possible.
37.9.12 Retainer Chains—The following are uses and considerations for selection of retainer chains:
37.9.12.1 Keep hatches or doors from opening too far and springing their hinges.
37.9.12.2 Turn doors or covers into useful shelves for the technician.
37.9.12.3 Prevent small covers, plates, or caps from being misplaced.
37.9.12.4 Secure small, special tools where they will be used.
37.9.12.5 Secure objects that might fall and injure personnel.
37.9.12.6 Secure removable pins to prevent loss.
37.9.12.7 Use link, sash, or woven-mesh chains. Avoid bead-link chain, because it breaks more easily than other types.
37.9.12.8 Attach chains with screws or bolts; attach them strongly and positively, but so they can be disconnected easily when required.
37.9.12.9 Provide eyelets at both ends of the chain for attaching to the fasteners.
37.9.12.10 Chains shall not be longer than their function requires.

38. Unit Design for Efficient Manual Handling

38.1 Rests and Stands—When required to support operations or maintenance functions, rests or stands on which units can be placed, including space for test equipment, tools, technical orders, and manuals, shall be provided. When permitted by design requirements, such rests or stands shall be part of the basic unit, rack, or console chassis.
38.2 Extensions—Extensions and connected appurtenances, accessories, utilities, cables, wave guides, hoses, and similar items shall be designed for easy removal or disconnection from the equipment before handling.
38.3 Weight Lifting and Carrying Limits:
38.3.1 Lifting Limits—The weight limits in Table 43, Conditions A and B, shall be used as maximum values in determining the design weight of items requiring one person lifting with two hands. Double the weight limits in Table 43 shall be used as maximum values in determining the design weight of items requiring two-person lifting, provided the load is uniformly distributed between the two lifters. If the weight of the load is not uniformly distributed, the weight limit applies to the heavier lift point. Where three or more persons are lifting simultaneously, not more than 75 % of the one-person value may be added for each additional lifter, provided that the object lifted is sufficiently large that the lifters do not interfere with one another while lifting. Where it is not possible to define the height to which an object will be lifted in operational use, the limit wherein the object is lifted to shoulder height shall be used rather than the more permissive bench height. The values in Table 43 are applicable to objects with or without handles.
38.3.2 Lifting Frequency—The equipment weight limits in Table 43 are not for repetitive lifting as found, for example, in loading or unloading transport vehicles. If the frequency of lift exceeds one lift in 5 min or 20 lifts per 8 h, the permissible weight limits shall be reduced by (8.33 × LF) %, where LF is the lift frequency in lifts per minute. For example, if the lift frequency is six lifts per minute, then the maximum permissible weight is reduced by 50 % (8.33 × 6 = 50).
38.3.3 Load Size—The maximum permissible weight limit in Table 43 are applicable to an object with uniform mass distribution and a compact size not exceeding 460 mm (18 in.) high, 460 mm (18 in.) wide, 300 mm (12 in.) deep (away from the lifter). This places the hand holds at half the depth, or 150 mm (6 in.) away from the body. If the depth of the object exceeds 610 mm (24 in.), the permissible weight shall be reduced by 33 %. If the depth of the object exceeds 910 mm (36 in.), the permissible weight shall be reduced by 50 %. If the depth of the object exceeds 1,220 m (48 in.), the permissible weight shall be reduced by 66 %.
38.3.4 Obstacles—The values in Table 43 assume that there are no obstacles between the person lifting and the shelf, table, bench, or other surface on which the object is to be placed. Where there is a lower protruding shelf or other obstacle limiting the lifter’s approach to the desired surface, the weight of the limit of the object shall be reduced by 33 % for an obstacle exceeding 300 mm (12 in.) in depth, 50 % for an obstacle exceeding 460 mm (18 in.), and 66 % for an obstacle of 610 mm (24 in.). If the allowable weight must be reduced by both oversize load considerations (38.3.3) and the obstacle considerations, only the more restrictive single value shall apply; two reductions shall not be applied.
38.3.5 Carrying Limits—The weight limit in Table 43 Condition C shall be used as the maximum value in determining the design weight of items requiring one person carrying objects a distance of up to 10 m (33 ft). The maximum permissible weight for carrying also applies to an object with a handle on top, such as a tool box, which usually is carried at the side with one hand. Double this weight-carrying limit shall be used as the maximum value in determining the design weight of items requiring two-person carrying, provided the load is uniformly distributed between the two carriers. Where three or more persons are carrying a load together, not more than 75 % of the one-person value may be added for each additional person and provided that the object is sufficiently large that the workers do not interfere with one another while carrying the load. In all cases involving carrying, it is assumed that the object is first lifted from the floor, carried a distance of up to 10 m (33 ft) or less and placed on the floor or on another surface not higher than 915 mm (36 in.). If the final lift is to a higher height, the 1.525-m (5-ft) lift height applies as the more limiting case.
38.3.6 Carrying Frequency—The reduction formula expressed in 38.3.2 shall be applied to repetitive carrying in the same manner as for repetitive lifting.
38.3.7 User Population—Unless otherwise specified by the procuring activity, the values in Table 43 for male and female
population shall apply to any object to be lifted or carried manually. Where the procuring activity specifies that the object is to be lifted or carried only in a combat environment, the male only population will be applied.

38.3.8 Labeling—Items weighing more than the one-person lift or carry values for male and female population of Table 43 shall be prominently labeled with weight of the object and lift limitation, that is, mechanical or two-person lift, three-person lift, and so forth. Where mechanical or power lift is required, hoist and lift points shall be provided and clearly labeled.

38.4 Push-and-Pull Forces:

38.4.1 Horizontal—Manual horizontal push-and-pull forces required to be applied initially to an object to set it in motion or to be sustained over a short period of time, shall not exceed the values of Fig. 108, as applicable. The values shown in Fig. 108 apply to males only and shall be modified for females. (Two thirds of each value shown is considered to be a reasonable adjustment). Use of the maxima shown in Fig. 108 is predicted upon a suitable surface for force exertion, vertical with rough surface, and be approximately 400 mm (16 in.) wide and between 51 and 127 cm (20 and 50 in.) above the floor to allow force application with the hands, the shoulder, or the back.

38.4.2 Vertical—Manual vertical push-and-pull forces required shall not exceed the applicable fifty percentile peak or mean force values of Table 44.

FIG. 108 Examples of Push-Pull Forces
TABLE 44 Static Muscle Strength Data

<table>
<thead>
<tr>
<th>Strength Measurements</th>
<th>5th Percentile</th>
<th>95th Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men N (lbf)</td>
<td>Women N (lbf)</td>
</tr>
<tr>
<td>Mean force</td>
<td>738 (166)</td>
<td>331 (74)</td>
</tr>
<tr>
<td>Peak force</td>
<td>845 (190)</td>
<td>397 (89)</td>
</tr>
</tbody>
</table>

Standing two-handed pull: 38-cm (15-in.) level
Mean force            | 758 (170)     | 326 (73)        |
Peak force            | 831 (187)     | 374 (84)        |

Standing two-handed pull: 50-cm (20-in.) level
Mean force            | 444 (100)     | 185 (42)        |
Peak force            | 504 (113)     | 218 (49)        |

Standing two-handed pull: 100-cm (39-in.) level
Mean force            | 215 (48)      | 103 (23)        |
Peak force            | 259 (58)      | 132 (30)        |

Seated one-handed pull: 150-cm (59-in.) level
Mean force            | 409 (92)      | 153 (34)        |
Peak force            | 473 (106)     | 188 (42)        |

Seated one-handed pull: 100-cm (39-in.) level
Mean force            | 227 (51)      | 106 (24)        |
Peak force            | 273 (61)      | 127 (29)        |

Seated one-handed pull: 50-cm (20-in.) level
Mean force            | 240 (54)      | 109 (25)        |
Peak force            | 273 (61)      | 134 (30)        |

Seated two-handed pull: 38-cm (15-in.) level
Mean force            | 595 (134)     | 242 (64)        |
Peak force            | 699 (157)     | 285 (64)        |

Seated two-handed pull: 50-cm (20-in.) level
Mean force            | 525 (118)     | 204 (46)        |
Peak force            | 596 (134)     | 237 (53)        |

38.5 Handle Dimensions—Handles that are to be used with mittened, gloved, or ungloved hands shall equal or exceed the minimum applicable dimensions shown in Fig. 109.

38.5.6 Handle Grasp Area Force Requirements—Force requirements to operate handle and grasp areas shall be in Section 21, Controls, General Information.

38.5.7 Handle Material—Handles or grasp areas used with bare hands shall have surfaces that are not thermally or electrically conductive. The surface shall be sufficiently hard to prevent imbedding of grit and grime during normal use.

38.5.8 Shape—Use hand-shape handles when items must be carried frequently or for long periods.

38.5.9 Hoist Lugs—Lifting eyes shall be provided on all equipment weighing more than 68 kg (150 lbs) with a minimum of 100 mm (4 in.) of space around the eye.

39. Handwheel Torque

39.1 Handwheel Torque—Fig. 110 contains information on desirable upper limits for handwheel torque. This data was from a very small sample and the most conservative values were used. Female values were extrapolated and are 60% of the male values. This information may be used for guidance in designing handwheels.

40. Equipment Mounting

40.1 General—Equipment items shall be designed so that they cannot be mounted improperly. Code, label, or key symmetrical components to indicate proper orientation for mounting or installation.

40.2 Tools—Field-removable items shall be replaceable by use of nothing more than common hand tools.

40.3 Removal—Replaceable items shall be removable along a straight or slightly curved line, rather than an angle.

40.4 Alignment—Guide pins or their equivalent shall be provided to assist in alignment during mounting, particularly on modules that are connectors themselves.

40.5 Coding—All replaceable items shall be coded (keyed) so that it will be physically impossible to insert a wrong item. Coding by such means as color or labels shall identify the correct item and its proper orientation or replacement.

40.6 Rollout Racks, Slides, or Hinges—Items that are frequently pulled out of their installed positions for checking shall be mounted on rollout racks, slides, or hinges. Rollout racks shall not shift the center of gravity to the extent that the entire rack or console falls. If this possibility exists, the console or rack shall be safely secured. The rollout racks shall operate with a force less than 178 N (4 lbs).

40.7 Limit Stops—Limit stops shall be provided on racks and drawers which are required to be pulled out of their installed positions for checking or maintenance. The limit stop design shall permit convenient overriding of stops for unit removal.

40.8 Interlocks—Where applicable, interlocks shall be provided to ensure disconnection of equipment that would otherwise be damaged by withdrawal of racks or drawers.

40.9 Hinged Mounting—Hinged items shall be provided with a brace or other means of support to hold equipment in the “out” position for maintenance it is not free to rotate and remain in the “out” position without support.
### FIG. 109 Minimum Handle Dimensions

**Braces**—Hinged items shall be provided with a brace or other means to hold equipment in the out position during checking or maintenance.  

**Access**—Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate their full distance and remain in the open position without

<table>
<thead>
<tr>
<th>ILLUSTRATION</th>
<th>TYPE OF HANDLE</th>
<th>DIMENSIONS IN mm (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Bare Hand)</td>
<td>(Gloved Hand)</td>
</tr>
<tr>
<td></td>
<td>X  Y  Z</td>
<td>X  Y  Z</td>
</tr>
<tr>
<td>Two-finger bar</td>
<td>32  65  75</td>
<td>38  75  75</td>
</tr>
<tr>
<td>(1 1/4) (2 1/2) (3)</td>
<td>(1 1/2) (3)</td>
<td></td>
</tr>
<tr>
<td>One-hand bar</td>
<td>48  111  75</td>
<td>50  125  100</td>
</tr>
<tr>
<td>(1 7/8) (4 3/8) (5)</td>
<td>(2) (5) (4)</td>
<td></td>
</tr>
<tr>
<td>Two-hand bar</td>
<td>48  215  75</td>
<td>50  270  100</td>
</tr>
<tr>
<td>(1 7/8) (8 1/2) (3)</td>
<td>(2) (10 1/2) (4)</td>
<td></td>
</tr>
<tr>
<td>T-bar</td>
<td>38  100  75</td>
<td>50  115  100</td>
</tr>
<tr>
<td>(1 1/2) (4) (3)</td>
<td>(2) (4 1/2) (4)</td>
<td></td>
</tr>
<tr>
<td>J-bar</td>
<td>50  100  75</td>
<td>50  115  100</td>
</tr>
<tr>
<td>(2) (4) (3)</td>
<td>(2) (4 1/2) (4)</td>
<td></td>
</tr>
<tr>
<td>Two-finger recess</td>
<td>32  65  50</td>
<td>38  75  50</td>
</tr>
<tr>
<td>(1 1/4) (2 1/2) (2)</td>
<td>(1 1/3) (3) (2)</td>
<td></td>
</tr>
<tr>
<td>One-hand recess</td>
<td>50  110  90</td>
<td>90  135  100</td>
</tr>
<tr>
<td>(2) (4 1/4) (3 1/2)</td>
<td>(3 1/2) (5 1/4) (4)</td>
<td></td>
</tr>
<tr>
<td>Finger-tip recess</td>
<td>19  —  25</td>
<td>19  —  (3/4)</td>
</tr>
<tr>
<td>(3/4) — (1/2)</td>
<td>(1) — (3/4)</td>
<td></td>
</tr>
<tr>
<td>One-finger recess</td>
<td>32  —  38</td>
<td>50  —  5</td>
</tr>
<tr>
<td>(1 1/4) — (2)</td>
<td>(1 1/2) — (2)</td>
<td></td>
</tr>
</tbody>
</table>

**Curvature of Handle or Edge**

<table>
<thead>
<tr>
<th>Weight of Item</th>
<th>Minimum Diameter</th>
<th>Gripping efficiency is best if finger can curl around handle or edge to any angle of 2/3 π rad 120° or more.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 15 lbs (6.8 kg)</td>
<td>D - 6 mm (1/4 in.)</td>
<td></td>
</tr>
<tr>
<td>15 to 20 lbs (6.8 to 9.0 kg)</td>
<td>D - 13 mm (1/2 in.)</td>
<td></td>
</tr>
<tr>
<td>20 to 40 lbs (9.0 to 18 kg)</td>
<td>D - 19 mm (3/4 in.)</td>
<td></td>
</tr>
<tr>
<td>Over 40 lbs (over 18 kg)</td>
<td>D - 25 mm (1 in.)</td>
<td></td>
</tr>
<tr>
<td>T-bar Post</td>
<td>T - 13 mm (1/2 in.)</td>
<td></td>
</tr>
</tbody>
</table>
being supported by hand. If access panels are provided do not require opening more than one to remove any single unit and keep all panel removals to a minimum.

40.12 Layout—Units shall be laid out so that a minimum of place-to-place movements will be required during checkout. Position components so the heavier ones are the easiest to reach. Keep components under 13.6 kg (30 lbs) where possible, with removal items under 20.5 kg (45 lbs) max. Place the heavy units so they can be slid out rather than lifted out. Difficult to reach items shall weigh less than 11.3 kg (25 lbs) and the 20.4-kg (45-lbs) items shall be placed for two-person handling.

40.13 Covers or Panels—Removal of any replaceable item shall require opening or removing a minimum number of covers or panels.

41. Conductors

41.1 Coding—Cables containing individually insulated conductors with a common sheath shall be coded.

41.2 Cable Clamps—Long conductors, bundles, or cables, internal to equipment, shall be secured to the equipment chassis by means of clamps unless contained in wiring ducts or cable retractors.

41.3 Length—Cables shall be long enough so that each functional unit can be checked in a convenient place. Extension cables shall be provided where this is not feasible.

41.4 Cable Routing—Cable routing shall not obstruct visual or physical access to equipment for operation or maintenance.

41.5 Location of Test Cables—If it is essential that test cables terminate on control and display panels, the test receptacles shall be so located that the test cables will not interfere with controls and displays.

41.6 Access—Cables shall be routed so as to be directly accessible for inspection and repair.

41.7 Susceptibility to Abuse—Cables shall be routed or protected in such a way that they may not be pinched by doors, lids, and so forth, walked on, used for handholds, or bent or twisted sharply or repeatedly.

41.8 Cable Protection—If it is necessary to route cables and wires through holes in mental partitions, the conductors shall be protected from mechanical damage or wear by grommets or equivalent means. Where required for NBC survivability, cables shall be wrapped and sealed.

41.9 Identification—Cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate. All replaceable wires and cables shall be uniquely

FIG. 110 Desirable Upper Limits for Handwheel Torque
identified with distinct color or number codes. Color-coded wires shall be color coded over their entire length. Number codes shall be repeated every 50 cm (20 in.) over the wire’s entire length.

42. Connectors

42.1 Use of Quick-Disconnect Plugs—Plugs requiring no more than one turn, or other quick-disconnect plugs, shall be provided whenever feasible.

42.2 Keying—Plugs shall be designed so that it will be impossible to insert a wrong plug in a receptacle or to insert a plug into the correct receptacle the wrong way.

42.3 Identification—Electrical plugs and receptacles shall be identified by color, shape, labels, or equivalent means (see Fig. 111). If labels are used, they shall be placed on the connector and receptacle, on plates attached to the connector and receptacle, or on tabs or tapes attached to the connector (in that order of preference).

42.4 Alignment—Plugs or receptacles shall be provided with aligning pins or equivalent devices to aid in alignment and to preclude inserting in other than the desired position.

42.5 Aligning Pins—Aligning pins shall extend beyond the plug’s electrical pins to ensure that alignment is obtained before the electrical pins engage. All aligning pins for a given plug or series of plugs shall be oriented in the same direction, unless this conflicts with precautions against mismatching.

42.6 Orientation—Plugs and receptacles shall be arranged so that the aligning pins or equivalent devices are oriented in the same relative position.

FIG. 111 Methods of Identifying Plugs and Receptacles to Prevent Mismatching
42.7 **Coding**—Plugs and receptacles shall have durable strips, arrows, or other indications to show the positions of aligning pins or equivalent devices for proper insertion.

42.8 **Spacing**—Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting. Space between adjacent connectors, or between a connector and any adjacent obstructions, shall be compatible with the size and shape of the plugs, and the type of clothing worn by the maintainer (for example, cold weather handwear, NBC gloves), but shall be not less than 25 mm (1 in.), except where connectors are to be sequentially removed and replaced and 25-mm (1-in.) clearance is provided in a swept area of at least 4.71 rad (270°) around each connector at the start of its removal/replacement sequence. Spacing shall be measured from the outermost portion of the connector, that is, from the backshell, strain relief clamp, dust cover, or EMI/RFI shield. Where high torque is required to tighten or loosen the connector, space shall be provided for use of a connector wrench.

42.9 **Testing and Servicing**—The rear of plug connectors shall be accessible for testing and servicing, except where precluded by potting, sealing, or other requirements.

42.10 **Drawer Modules**—Drawer modules designed for remove-and-replace maintenance shall be provided with connectors mounted on the back of the drawer and mated with connectors in the cabinet to accomplish electrical interconnection between the drawer, other equipment in the rack, and external connectors, where feasible. Guide pins or equivalent devices shall be provided to aid in alignment.

42.10.1 **Electronic Modules**—Replacement electronic items (for example, modules and high-failure-rate components) should be provided with simple plug-in, rack-and-panel-type connectors.

42.11 **Simplicity**—In electronic equipment, replacement items (for example, modules and high-failure-rate components) shall normally be provided with simple plug-in connectors.

42.12 **Disassembly and Adapters**—Disassembly of connectors for reasons of changing pin connections shall be easily performed without special tools. When adapters are required, they shall be capable of being hand-tightened.

42.13 **Dust Covers**—If dust covers are required, captive types shall be used.

43. **Electrical Wires and Cables**

43.1 **Routing**—Wherever possible, cables should be routed over, rather than under pipes or fluid containers. Route cables so that they are not pinched by doors, lids, and slides; are not walked on or used for handholds; are accessible to the technician, that is, are not under floorboards, behind panels or components that are difficult to remove, or routed through congested areas, and need not be bent or unbent sharply when connected or disconnected (Fig. 112 and Fig. 113).

43.2 **Coding**—Each cable or wire shall be labeled or coded throughout its entire length. Labels installed at a bench preparatory site shall be placed so they will be visible, and in the proper orientation to the reader, once the wire or cable is installed.

43.3 **Leads**—Enough slack shall be provided so terminal fittings can be replaced at least twice and preferably three times.

43.4 **Fan Out in Junction Boxes**—Cables shall fan out in junction boxes for easy checking, especially if there are no other test points in the circuits (see Fig. 113). Each terminal in the junction box shall be clearly labeled and easy to reach with test probes.

43.5 **Location of Junction Boxes**—Junction boxes that contain many wires (for example, IC junction boxes) which will require continued access after installation shall not be located under false decks or other difficult places to reach.

43.6 **Preformed Cables**—Use preformed cables when possible (Fig. 114). They permit flexible, more efficient assembly methods and minimize the chances of making wiring errors. They also permit testing and coding of the entire cable before installation. Once the cable is placed in position on the chassis, the leads can be connected without interference and confusion caused by stray wires.
44. Test Points

44.1 Adjustment—Test points used in adjusting a unit shall be located close to the controls and displays.

44.2 Troubleshooting—Sufficient test points shall be provided so that it will not be necessary to remove subassemblies from assemblies to accomplish troubleshooting.

44.3 Location—Test points and their associated labels and controls shall be located so they face the user in their test position.

44.4 Design Considerations—Test points shall be provided, designed, and located as follows:

44.4.1 So that there will be a minimum of disassembly or removal of other equipment or items.

44.4.2 On surfaces on or behind accesses that may be easily reached or readily operated when the equipment is fully assembled and installed.

44.4.3 So that adequate clearance is provided between connectors, probes, controls, and so forth, for easy grasping and manipulation. The following minimum clearances are recommended:

44.4.3.1 When only finger control is required, 19 mm (0.75 in.).

44.4.3.2 When the gloved hand must be used, 75 mm (3 in.).

44.4.4 With guards and shields to protect personnel and test or service equipment, particularly if the equipment must be serviced while operating.

44.4.5 To avoid locating a single test or service point in an isolated position; such points are most likely to be overlooked or neglected.

44.4.6 With windows to internal items requiring frequent visual inspections, such as gages, indicators, and so forth.

44.4.7 With tool guides and other design features to facilitate operation of test or service points that require blind operation.

44.4.8 Within easy functional reaching or seeing distance of related or corresponding controls, displays, fittings, switches, and so forth.

44.4.9 Away from dangerous electrical, mechanical, or other hazards. A hands-width separation of 115 mm (4.5 in.) shall be provided from the nearest hazard, along with guards and shields, to prevent injury.

44.5 Adjustment Controls—Where adjustment controls are associated with test and service points, they shall be designed and positioned so that:

44.5.1 They are capable of being quickly returned to the original settings to minimize realignment time if they are inadvertently moved.

44.5.2 Adjustments are independent of each other whenever possible.

44.5.3 Those that require sequential adjustment are located in the proper sequence and marked to designate the order of adjustment.

44.5.4 Knobs are used in preference to screwdriver adjustments except where inadvertent or unauthorized adjustments want to be avoided. In those cases, a screwdriver adjustment is preferred.

45. Test Equipment

45.1 Storage—Adequate storage space shall be provided within portable test equipment, its handling case, or lid to contain leads, probes, spares, manuals, and special tools, as required for operation.

45.2 Instructions—Instructions for operating portable test equipment shall be provided on the face of the test equipment, in a lid, or in a special compartment. Where applicable, the instructions shall include a reminder to calibrate the equipment before using it.

45.3 Switches—Selector switches shall be used instead of a number of plug in connections. Circuit breakers and fuses shall be used to safeguard against damage if the wrong switch or jack position is used.

45.4 Portable Test Equipment Design:

45.4.1 Rectangular or square shapes are recommended with dimensions to fit standard electrical racks if possible.

45.4.2 Stands or casters shall be provided for devices weighing more than 13.6 kg (30 lbs). Wheels, casters, or hoist-lifting shall be provided for devices weighing more than 40.8 kg (90 lbs).

45.4.3 Portable test equipment shall have rounded corners and edges.

45.4.4 Hinged, permanently attached covers are recommended.

45.4.5 The weight and dimensions of portable test equipment shall not exceed those listed in Table 45.

45.4.6 Instructions shall be written in a simple language and printed large enough to be seen in low light.

46. Failure Indications and Fuse Requirements

46.1 Indication of Equipment Failure:

<table>
<thead>
<tr>
<th>TABLE 45 Weight and Dimensions of Portable Test Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Weight, kg (lb)</td>
</tr>
<tr>
<td>Height, mm (in)</td>
</tr>
<tr>
<td>Length, mm (in.)</td>
</tr>
<tr>
<td>Width, mm (in.)</td>
</tr>
</tbody>
</table>
46.1 Power Failure—An indication shall be provided to reveal when power failure occurs. All mission-essential electronic computer and peripheral components that are part of a system shall incorporate an automatic self-check diagnostic of software and hardware at power up and at the request of the operator to assure they are functioning properly.

46.1.2 Out of Tolerance—Displays shall be provided to indicate when equipment has failed or is not operating within tolerance limits.

46.1.3 Critical Malfunctions—If equipment is not regularly monitored, an auditory alarm shall be provided to indicate critical malfunctions.

46.2 Fuses and Circuit Breakers:

46.2.1 General—When required by the system, a positive indication shall be provided to reveal that a fuse or circuit breaker has opened a circuit.

46.2.2 Replacement and Resetting—Fuses shall be readily accessible for removal and replacement. No other components shall require removal to gain access to fuses. No special tools shall be required for fuse replacement unless required by safety considerations. When resetting of circuit breakers is permissible, and is required for system operation during a mission, the breaker shall be located within reach of crew members in their normal operating posture.

46.2.3 Markings—The area of equipment served by the fuse or circuit breaker shall be identified. The current rating of fuses shall be permanently marked adjacent to the fuse holder. In addition, SPARE shall be marked adjacent to each spare fuse holder. Fuse ratings shall be indicated either in whole numbers, common fractions (such as \( \frac{1}{4} \)), or whole number and common fractions (such as \( 2\frac{1}{4} \)). Labeling of fuses and circuit breakers shall be legible in the anticipated ambient illumination range of the operator’s location.

46.2.4 Circuit Breaker Controls—Toggle bat and legend switch-actuated circuit breakers may be used to control electrical power. Push-pull-type breakers shall not be used as power switches.

46.2.5 Printed Circuit Boards—Printed circuit boards shall be designed and mounted for ease of removal and replacement, considering such factors as finger access, gripping aids, and resistance created by the mounting device. Appropriate feedback shall be provided to insulate the technician knows when the board is securely connected. Printed circuit boards shall be identified in accordance with MIL-STD-130 and reference designations for parts mounted on the printed circuit board shall be provided in accordance with MIL-STD-454, Requirement 67. These standards are applicable only to military vessels.

46.2.6 Circuit Breaker Dimensions and Separations—Dimensions and separation for toggle bat-actuated breakers shall comply with Fig. 42. Legend switch-actuated breakers shall comply with the dimension and separation criteria shown in Fig. 44. Push-pull-actuated circuit breaker separation shall comply with Fig. 47.

46.3 Other Design Considerations:

46.3.1 Fuses, or circuit breakers, shall be provided so that each unit of a system is separately fused and adequately protected from harmful powerline variations or transient voltages.

46.3.2 Fuses shall be located on the front or side panel of the unit where they can be seen and replaced without removing other parts. Fuses shall not be located inside the equipment.

46.3.3 Fuses shall be grouped in a minimum number of central, readily accessible locations and shall be replaceable by the equipment operator whenever possible, without the use of tools.

46.3.4 Cups or caps shall be the quick-disconnect, rather than the screw-in type; they shall be knurled and large enough to be removed easily by hand.

46.3.5 Fuse installations shall be designed so that only the cold terminal of the fuse can be touched by personnel.

46.3.6 When selecting fuses or circuit breakers, consider the suitability of each to perform a particular function (Table 46). There are two types of circuit breakers, thermal air and magnetic air. Thermal air circuit breakers are used primarily for overcurrent circuit protection. They are best adapted to dc circuits up to 250 V and to ac circuits up to 600 V in capacities up to 600 A. Magnetic air circuit breakers may be used to provide protection in event of overcurrent, undercurrent, reverse current, low voltage, reverse phase, and so forth.

46.4 Printed Circuit Boards—Printed circuit boards shall be designed and mounted for ease of removal and replacement, considering such factors as finger access, gripping aids, and resistance created by the mounting device. Appropriate feedback shall be provided to ensure that the technician knows when the board is securely connected.

47. Hydraulic Systems

47.1 Standardization:

47.1.1 Connectors in hydraulic systems shall be of standard design and handled with standard tools.

47.1.2 Standardize, where practical, valves and cylinders, hose assemblies, couplings, fittings, and filters.

47.1.3 Use standard hardware for mounting hydraulic components.

47.1.4 Ensure that all connectors are standardized by content of lines, and that the number of different sizes are held to a minimum. If there is a danger of mismating connectors for adjacent lines carrying different fluids, specify physically incompatible connectors for the two lines.

47.2 Identification:

<table>
<thead>
<tr>
<th>Function</th>
<th>Circuit Breaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous action</td>
<td>X</td>
</tr>
<tr>
<td>Time delay features</td>
<td>X X X</td>
</tr>
<tr>
<td>Resetting</td>
<td>X</td>
</tr>
<tr>
<td>Adjustable tripping range for other than maximum setting</td>
<td>X</td>
</tr>
<tr>
<td>Automatic resetting</td>
<td>X</td>
</tr>
<tr>
<td>Remote control resetting and tripping</td>
<td>X</td>
</tr>
<tr>
<td>Overcurrent protection low current, reverse current, reverse phase, and low-voltage protection</td>
<td>X X X</td>
</tr>
</tbody>
</table>

TABLE 46 General Comparison Fuses and Circuit Breakers
47.2.1 Use color coding for hydraulic lines, valves, and so forth, at each end of the line.

47.2.2 Provide permanent identification and instruction markings and indicate periodic inspection and drain schedules on them.

47.2.3 Inlets, outlets, and connecting lines in hydraulic systems shall be identified at least every 460 mm (18 in.), and at both ends, to facilitate maintenance.

47.3 Drain Cocks—All drain cocks shall be closed when the handle is in the down position. Those with a high rate drainage shall be fitted to all air receivers and oil reservoirs.

47.4 Seals—Seals that are visible externally after they are installed, since costly accidents result when seals are left out during assembly or repair, are preferred. However, O-ring seals are permitted. Seals shall not protrude or extrude beyond the coupling since protruding seals are chipped and shredded by vibration or contact, and the damage spreads internally to destroy sealing power and deposit pieces in the line. For low-temperature operation, use special low-temperature materials.

47.4.1 Specify couplings that use permanent seals rather than those that must be removed and replaced when the seal wears out.

47.5 Design Considerations—Hydraulic systems design shall consider the following: (See Fig. 115.)

47.5.1 Provide mechanical stops for valve handles to prevent the valves from opening because of vibrations.
47.5.2 Self-sealing couplings shall be provided on complex hydraulic and pneumatic systems to simplify identification.
47.5.3 Consider the use of armor-covered flexible hose for hydraulic lines to facilitate replacement in the field form bulk stock.
47.5.4 Use aircraft-type safety fittings with built-in check valves in hydraulic lines to limit fluid loss in the event of a line rupture.
47.5.5 Design for automatic bleeding of hydraulic systems whenever possible.

48. Design of Equipment For Remote Handling

48.1 Characteristics of Equipment to be Handled Remotely:
48.1.1 Alignment—Self-alignment devices shall be provided for components that must be joined remotely.
48.1.2 Disconnect—Quick-disconnect devices shall be provided to reduce remote-handling difficulties.
48.1.3 Fasteners—All fasteners shall be captive and readily replaceable by remote-handling techniques.
48.1.4 Lock and Latching Mechanisms—Each lock or latching mechanism shall be operable from a single point, have a positive catch, and provide a clear visual indication of the latch position.
48.2 Feedback—Provision shall be made for transmitting information from remote work areas to the operator of the remote-handling system. Visual information shall be regarded as most critical, followed, in order, by kinesthetic, tactual, and auditory feedback.

48.3 Manipulatory:
48.3.1 Safety—Power manipulators shall be provided with positive stops to prevent accidents.
48.3.2 Characteristics—For tasks that require manipulative dexterity and load capacities of less than 10 kg (22 lbs), manipulators with the following characteristics shall be provided:
48.3.2.1 Position control (that is, zero-order control in which the operator’s control output directly determines the machine output).
48.3.2.2 Mutual force reflection between control and effector.
48.3.2.3 Seven degrees of freedom in motion and force control (that is, three for translation, three for rotation, and one for gripping).
48.3.3 Power Assist—For tasks involving gross positioning of loads heavier than 10 kg (22 lbs), electrically or hydraulically powered manipulators with rate control shall be provided (that is, the operator’s control output directly determines the rate of change of the machine output).

48.4 Viewing Equipment:
48.4.1 General—A viewing system shall be provided which gives the operator of a remote manipulator adequate information with respect to the three spatial coordinates of the workspace (that is, X, Y, and Z).
48.4.2 Direct Viewing—When permitted by shielding requirements, provision shall be made for the operator to view the work directly through shielding windows.

48.4.3 Viewing Angle—To avoid distortion, requirements shall be minimized for direct viewing of objects either near the viewing window or at line-of-sight angles at incidence greater than 105 rad (60°).

48.4.4 Indirect Viewing—Applicable viewing systems, such as closed-circuit television systems, periscopes, and microscopes, shall be provided to supplement direct viewing, where required by specific remote-handling situations.

48.4.5 Coding—Symbol or pattern coding shall be used in preference to color coding for television viewing.

48.4.6 Lettering—Letters, numbers, and important details that must be viewed by means of television shall be light whenever possible.

48.4.7 Use quick-release fastening devices on connections that require frequent disconnection. Provide self-sealing features to prevent leakage of fluid when disconnect is made.

48.4.8 Use valves with integral limit switches where practicable.

48.4.9 Use permanent or cartridge-type fasteners.

48.4.10 Provide, in case of electrical failure, a means for manually operating hydraulic systems.

48.4.11 Consider the connector recommendations shown in Fig. 114.

48.4.12 To prevent fluid spraying or draining on the technician or nearby objects when fluid lines are disconnected during maintenance, use the following design recommendations:
48.4.12.1 Provide line drains to ground or container at low-level access points.
48.4.12.2 Reposition line disconnects from sensitive components or shield the component.
48.4.12.3 Provide a high-visibility warning light at disconnect areas that are especially critical against a dark background. Glazed or reflecting surfaces shall be avoided.

48.4.13 Stereo Viewing—The two images produced by a stereoscopic periscope shall not differ more than 2% in magnification or 0.50 prism diopter in vertical imbalance. Horizontal imbalance shall be no greater than 0.50 prism diopter so as not to be fatiguing. Light transmittance of the two optical paths shall be within 10% of each other.

48.5 Illumination:

48.5.1 Reflected Light—Lighting provided in remote work areas shall be such that reflected light, as measured at the operator’s work station (in direct viewing), will conform with the requirements of this standard, or as otherwise specified by the procuring activity.

48.5.2 Threshold Viewing—Monochromatic lighting shall be provided when viewing conditions are near threshold, when high magnification powers are required, or when the operator is required to view the work at high angles of incidence through refractive materials.

49. Small Systems and Equipment

49.1 Portability and Load Carrying—Individual portions of equipment shall be designed so that, when carried, the weight of the load will be distributed through as many muscle groups as possible. Pressure shall be avoided or minimized on sensitive areas, including large blood vessels, nerves, and areas lacking muscular padding. Design of load-carrying systems
shall consider the weight and distribution of individual items to
be carried by the user. The weight of the items to be carried
varies according to the climatic zone, mission to be performed,
and occupational specialty. Load-carrying systems shall be
provided with a quick-release capability.

49.1.1 Portability:
49.1.1.1 Weight—Individual portions of equipment may
weigh up to 16 kg (35 lbs) if the load is balanced and is
distributed over many muscle groups and it is not necessary for
the individual carrying the load to maintain the pace of an
infantry movement.

49.1.1.2 Lifting Aids—When necessary, lifting aids shall be
provided to permit a second person to assist the porter in
placing the load on the body.

49.1.1.3 Configuration—The load shall be designed to per-
mit freedom of movement. The shape of the load shall be free
of sharp edges or projections that may be harmful to the porter
or snag on undergrowth. The shape and weight of the load shall
not interfere with:
   (a) The length of step.
   (b) Movements of the head.
   (c) The ability to raise and lower the load when going over
      obstacles.
   (d) The ability to see where the feet are placed when
      walking.
   (e) The ability to squat.
   (f) Regulation of body temperature.
   (g) The maintenance of normal posture.

49.1.1.4 Carrying by Two Persons—Where the load is
designed for carrying by two persons, a combination of
stretcher-type handles and shoulder support shall be used, if
feasible.

49.1.1.5 Standardization—Maximum use shall be made of
standard load-carrying systems or components.

49.1.2 Transportability by Personnel—Systems that include
a requirement for transportability by personnel shall conform
to the following provisions:

49.1.2.1 Weight—Individual portions of equipment shall be
designed to weigh as little as possible if the system is to be
manually transported by an individual on foot while maintain-
ing pace with an infantry movement.

49.1.2.2 Load Carrying—The total load carried by an indi-
vidual, including clothing, weapons, and equipment for close
combat operations shall not exceed 30 % of body weight and,
for marching, 45 % of body weight. Where personnel with fifth
percentile body weight must be accommodated, the total load
shall not exceed 24.5 kg (54 lbs).

49.1.2.3 Lifting Aids—Units shall be equipped with handles
suitable for two-handed lifting and carrying. The provisions of
38.5 shall apply.

49.2 Optical Instruments and Related Equipment:
49.2.1 General—This section pertains only to direct-view,
visual optical systems. The information is presented so that
human capabilities and limitations can be considered in the
design, engineering, operation, and maintenance of optical
equipment. Detailed instrument parameters, characteristics,
and so forth, shall be a function of governing applications and
user requirements.

49.2.2 Visual Accommodation—Any adjustment of the eyes
beyond normal functional ability shall not be required.

49.2.3 Viewing Angle—Optical instruments shall be or-
iented so that they are presented to the operator at an angle
comfortable for viewing.

49.2.4 Magnification:
49.2.4.1 General—Instrument magnification shall be suffi-
ciently high to permit performance of the required application,
such as detection, recognition, identification, laying, and so
forth.

49.2.4.2 Unstabilized, Unsupported Handheld Sights—
Because of hand tremors and body motion, magnification of
unstabilized, unsupported handheld sights shall not exceed 8
power for monoculars or binoculars.

49.2.4.3 Multiple Magnification Requirements—If more
than one magnification is required, two or more discrete
magnifications shall be provided for optimum image quality
and boresight integrity. Varifocal (zoom) systems shall be
considered for use only in systems where sighting accuracy is
relatively unimportant and it results in overall simplification.

49.2.5 Field of View—Field of view shall be compatible
with intended use and optical/mechanical design limitations.

49.2.6 Entrance Pupil—The entrance pupil shall be equal to
the product of the magnification and the exit pupil diameter
and, therefore, defined by these parameters.

49.2.7 Exit Pupil:
49.2.7.1 General—The diameter of the exit pupil shall be
consistent with intended use and size/weight limitations.

49.2.7.2 Daylight—For daylight application, the exit pupil
diameter shall not be less than 3 mm (0.12 in.).

49.2.7.3 Low-Light Levels—For maximizing performance
at twilight and lower light levels, the exit pupil shall not be less
than 7 mm (0.28 in.).

49.2.8 Eye Relief—A long eye relief (for example, 25 mm
(1 in.)), is ordinarily desirable for vehicular-mounted sights to
observe on the move and to afford some field-of-view while
wearing a protective mask. The required eye relief depends
upon the particular application, but shall be at least 15 mm (0.6
in.) to permit use by observers wearing glasses.

49.2.9 Eyepiece Adjustments:
49.2.9.1 4-Power and Less—Fixed focus eyepieces set be-
tween −0.50 and −1.00 diopter may be used for instruments
4-power and less.

49.2.9.2 Over 4-Power—Eyepiece dioptic (focusing) ad-
justments (−4 to +2 dipters required, −6 to +2 dipters
desired) shall be provided and marked in 0.5-dipter incre-
ments on all instruments over 4-power magnification.

49.2.10 Optical Quality:
49.2.10.1 Axial Resolution—Axial resolution shall be equal
to or better than 300 µrad (1 min) divided by the magnification
to provide an eye-limited instrument.

49.2.10.2 Luminous Transmission—Luminous transmission
shall be as high as possible, preferably greater than 50 %.

49.2.11 Reticles:
49.2.11.1 Line Thickness—Reticule lines shall be thin
enough so as not to obscure targets, but thick enough to be
easily seen. Reticule lines shall subtend a minimum of 600 µrad
(2 min) at the eye.
49.2.11.2 Patterns—Reticle patterns shall be as simple as possible and restricted to one main mission per reticle glass. Additional patterns shall be on separate reticle glasses if added complexity is warranted for the particular application.

49.2.11.3 Format—Line reticle shall be used in preference to reticle containing one, two, or three central spots. A small cross or very small circle shall be used in preference to a dot.

49.2.11.4 Parallax—The reticle shall be focused to the target range of primary interest to limit the parallax to an acceptable value throughout the usable range.

49.2.12 Illuminated Sights and Reticles:

49.2.12.1 Night Operations—Illuminated reticle shall be provided for sights to be used during twilight or night operations.

49.2.12.2 Color—Blue shall not be used as the color if illumination for reticle or sights.

49.2.12.3 Dimming—It shall be possible to gradually lower the luminance of a sight until it is extinguished.

49.2.12.4 Illumination Level—The illumination level of a sight (once an adjustment is made) shall remain fixed under all conditions of vibration.

49.2.12.5 Uniformity—Illuminated sights shall be evenly illuminated by means of an opal diffuser or similar device.

49.2.12.6 Reticle Lines—Reticle lines for illuminated sights shall be 150-µrad (0.5-min) visual angle or more in thickness. They shall be thin enough so as not to obscure targets, but thick enough to be easily seen. In any case, their thickness shall not exceed 600 µrad (2 min).

49.2.13 Binoculars/Bioculars:

49.2.13.1 Binocular Viewing—Where continuous use of a sight under low levels of illumination will exceed 1 min, the single optical train shall be provided with two eyepieces, if this does not lead to unacceptable light losses.

49.2.13.2 Eyepiece Separation—Binocular/biocular instruments shall have an eyepiece separation scaled from 50 to 73 mm with 1-mm interval markings.

49.2.13.3 Magnification Differences—Magnification differences of two barrels shall not exceed 2 %.

49.2.13.4 Luminous Transmission Differences—Luminous transmission differences of the two barrels shall not exceed 5 %.

49.2.13.5 Matched Oculars—To avoid size differences in the images supplied to the two eyes, hence eyestrain and headache or both, oculars shall be matched in focal length, that is, shall be matched pairs.

49.2.13.6 Weight—Weight of handheld binocular/bioculars shall not exceed 1 kg (2.2 lbs) and shall not exceed 1.5 kg (3.3 lbs).

49.2.13.7 Size and Configuration—Instrument size and configuration shall be compatible with anthropometric requirements of Section 30.

49.2.14 Eyecups and Headrests—Any optical instrument requiring steady orientation of the eyes shall be provided with a headrest or eyecups, or both.

49.2.14.1 Eyecups—Eyecups shall be provided to maintain proper eye relief, eliminate stray light, and, when required, to protect or cushion the eyes and orbital region against impact with the eyepieces. The radii of Fig. 116 defines a surface of revolution within which a satisfactory symmetrical eyepiece and cup must be designed if interferences with facial features are to be avoided. These shall be applied to cushion forms when they are compressed to the maximum.

49.2.14.2 Headrests/Browpads—A headrest or brow pad shall be used to absorb energy which would be injurious to the operator’s head.

49.2.14.3 Compatibility with Clothing and Personal Equipment—Eyecups and headrests shall be compatible with helmets, protective masks, and other clothing and personal equipment.

49.2.15 Accessories:

49.2.15.1 Filters:

(a) General—Light filters, removable from the optical path, shall be provided to reduce glare, light intensity, or protect the observer’s eyes against hazardous light levels. Provisions shall be made for filter stowage, where applicable.

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**FIG. 116 Anatomical Limits on Axially Symmetrical Ocular Metal Part**

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| A - SUPERCIALLY ARCH REQUIREMENT | 17 mm (1/16 in) |
| B - NASAL BONE REQUIREMENT | 22 mm (7/8 in) |
| C - GREATER ALAR CARTILAGE REQUIREMENT | 32 mm (1 1/4 in) |
| D - SEPTAL CARTILAGE REQUIREMENT | 44 mm (1 3/4 in) |

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(b) Use—Use of color or neutral density filters will depend upon the application. For use in observing bright light sources, neutral filters shall be considered for reducing overall brightness without affecting contrast. The use of polarizing filters shall be considered where it is necessary to reduce glare and increase apparent contrast from sun, snow, or water.

49.2.15.2 Shutter—Shutters having closure and reopening times appropriate for each application may be provided in lieu of fixed filters to protect the observer exposed to flashes from weapon systems, lasers, or nuclear devices. Shutter for protection from the observer’s own weapon system flash, which may be actuated just before the weapon is fired, shall not disturb the lay of the weapon before closing nor unnecessarily impede the observation of the projectile flight path or resultant impact.

49.2.15.3 Positioning Aids—Level vials, scales, pointers, and other devices required for positioning the instrument shall be readily visible and protected from damage of displacement.

49.2.16 Environmental Conditions—Carry/transport cases shall be provided for instruments to be hand-carried or mounted/dismounted separately. Instruments to be used under severe environmental conditions shall be designed to take into consideration the special clothing, headgear, protective masks, or other ancillary equipment required by the operator, affecting controls, eyepieces, eyecups, headrests, and other operator interfaces.

49.2.17 Lighting—Means shall be provided for illumination of internal and external scales, level vials, and so forth, under low-light-level conditions. Continuously variable control of illumination shall be provided as required by weapon system characteristics. Illumination under low-light-level conditions shall be designed to minimize the dark adaptation of the observer. Red illumination or red filters shall be used to maintain dark adaptation.

49.2.18 Maintenance:

49.2.18.1 Modular Design—When practical, optical equipment shall be developed using modular design to provide for interchangeability of optical subassemblies.

49.2.18.2 Positioning Aids—Built-in aligning devices and other aids shall be used whenever possible for ease of positioning optical assemblies within an instrument or optical modules that have multiple applications in equipment.

49.2.18.3 Quick Release—Quick-release methods of removing optical instruments shall be used wherever practical.

49.2.18.4 Collimation—Optical instruments shall be provided with built-in collimation features to allow field adjustment.

49.2.18.5 Purging and Charging—Where periodic purging and charging of optical instruments are required, an instruction plate, indicating time interval and pressure requirements, shall be accessible. Purging and charging fittings shall be accessible for required maintenance.

49.2.18.6 Component Replacement—Internal components such as light bulbs that require frequent replacement, checkout or maintenance shall be easily accessible, removable without special tools, and replaceable without removal or disassembly or other components. Components that require frequent replacement and frequently used special tools or equipment or both shall be readily accessible. Provision shall be made for storage of such components and tools in or on the specific equipment. This particularly applies to items such as light bulbs whose failure could make the instrument inoperable.

50. Operational and Maintenance Vehicles

50.1 General—Handles, levers, pedals, knobs, and workspace dimensions shall be designed to enhance effective vehicle operation by suitably clothed and equipped users with relevant body dimensions varying between fifth and ninety-fifth percentiles (See Section 30).

50.2 Seating:

50.2.1 Dimensions and Clearances—Seating for vehicle operators shall follow the dimensions and clearances recommended in Fig. 54 and Fig. 55, and Table 47, as applicable.

50.2.2 Vertical Adjustment—If the seat’s height above the floor is variable, requirements for leg room and footrest will also vary. When the seat is adjusted higher, there will be more leg room and larger footrest angles.

50.2.3 Horizontal Adjustment—Seats shall adjust at least 150 mm (6 in.) in the fore-aft direction.

50.2.4 Back Rest—Back-rest angle shall be not more than 1920 mrad (110°) from horizontal. If only the lumbar area is supported, the backrest angle of tilt shall be 1660 to 1745 mrad (95 to 100°) for operators in an alert position.

50.2.5 Seat Pan—The seat pan shall be flat and made from a rigid material.

50.2.6 Seat Padding—Seat padding shall be kept to a minimum, but it shall be resilient enough to keep the operator’s body from contacting the seat bottom during severe vibration. Seat padding made of foam-type material shall be adequately ventilated.

50.2.7 Seat Belts—All administrative-type vehicles shall have safety seat belts. Seat belts shall be installed on other types of vehicles except when they interfere with operational requirements.

50.3 Controls:

<table>
<thead>
<tr>
<th>TABLE 47 Recommended Clearances Around Equipment Operator’s Station to Accommodate 95th Percentile Male Dressed in Arctic Clothing, Operator Seat in Rear Most Position</th>
<th>mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Elbow (dynamic)</td>
<td>910 (36)</td>
</tr>
<tr>
<td>B. Elbow (static)</td>
<td>710 (28)</td>
</tr>
<tr>
<td>C. Shoulder</td>
<td>580 (23)</td>
</tr>
<tr>
<td>D. Knee width (minimum)</td>
<td>460 (18)</td>
</tr>
<tr>
<td>E. Knee width (optimum)</td>
<td>610 (24)</td>
</tr>
<tr>
<td>F. Boot—provide adequate clearance to operate brake pedal</td>
<td>150 (6)</td>
</tr>
<tr>
<td>without inadvertent acceleration operation</td>
<td></td>
</tr>
<tr>
<td>G. Pedals (minimum)</td>
<td>50 (2)</td>
</tr>
<tr>
<td>H. Boot—provide adequate clearance to operate accelerator</td>
<td>150 (6)</td>
</tr>
<tr>
<td>without interference by brake pedal</td>
<td></td>
</tr>
<tr>
<td>1. Head (SRP to roof line)</td>
<td>1070 (42)</td>
</tr>
<tr>
<td>2. Abdominal (seat back to steering wheel)</td>
<td>410 (16)</td>
</tr>
<tr>
<td>3. Front of knee (seat back to manuals/controls on dash)</td>
<td>740 (29)</td>
</tr>
<tr>
<td>4. Seat depth (seat reference point to front edge of seat pan)</td>
<td>410 (16)</td>
</tr>
<tr>
<td>5. Thigh—under side of steering wheel to seat pan</td>
<td>240 (9.5)</td>
</tr>
<tr>
<td>6. Seat pan height</td>
<td>380 (15)</td>
</tr>
<tr>
<td>7. Boot (front of seat pan to heel point of accelerator)</td>
<td>360 (14)</td>
</tr>
<tr>
<td>8. Minimum mitten clearance around steering wheel</td>
<td>75 (3)</td>
</tr>
<tr>
<td>9. Knee—leg—thigh (brake–clutch pedal) to lower edge of</td>
<td>660 (26)</td>
</tr>
<tr>
<td>steering wheel</td>
<td></td>
</tr>
</tbody>
</table>
50.3.1 **Design**—Controls shall be designed so as not to be adversely affected by distortion, shock, or vibration of the vehicle.

50.3.2 **Steering**—In case of power steering assist failure, the steering gear shall afford the operator sufficient mechanical advantage to guide the vehicle during an emergency stop or during low-speed operation (see Fig. 37 for quantitative data.)

50.3.3 **Pedals**—Foot pedals shall be designed to accept the weight of the operator’s foot without initiating control action.

50.3.4 **Control of Hazardous Operations**—The operation of switches or controls that initiate hazardous operations shall require the prior operation of a locking control.

50.4 **Operating Instructions:**

50.4.1 **Provisions of Operating Instruction**—Operating instructions shall be provided for all vehicles and vehicle equipment, except where the mode of operation will be obvious to all potential operators.

50.4.2 **Format**—Information shall be presented in the form of diagrams whenever possible.

50.4.3 **Speed Notice**—Maximum permissible road speeds in each gear and range shall be indicated. On vehicles for which all road speeds are limited by engine speed, a red line on the tachometer (if so equipped), at maximum engine RPM, may be used in lieu of a speed placard.

50.4.4 **Shift Handle Position**—Operating positions of shift handles, such as transmission, power take-off, winch-control, and transfer case mechanisms shall be illustrated.

50.4.5 **Control Movements**—Control movements shall be shown in planes parallel to the movement of the actual controls.

50.4.6 **General Labeling Criteria**—Identification and instruction markings shall conform with the criteria for labeling contained in this standard.

50.5 **Visibility:**

50.5.1 **Night Operation**—Indicators required by the vehicle operator during night operation shall be illuminated. The display luminance shall be adjustable from 0.1 to 3.5 cd/m² (0.03 to 1.0 ft-L). Blackout lighting systems, if required, shall be designed to preclude accidental operation of external lights and signals.

50.5.2 **Visual Field**—The operator shall have forward visibility through a lateral visual field of at least π rad (180° preferably 3840 mrad (220°)).

50.5.3 **Glare**—Appropriate use shall be made of visors or other means to preclude performance degradation caused by glare from external sources such as sunlight or headlights except that windshields or other transparent areas through which high-acuity vision is required shall not be tinted or colored.

50.5.4 **Windshields and Windows**—Transparent materials selected for windshield and windows shall be shatterproof and shall neither distort nor obscure vision.

50.5.5 **Windshields Wipers and Washers**—Windshield wipers and washers shall be provided. Blades shall return to the stored position when turned OFF. Provisions shall be made for manual operation in event of power failure.

50.5.6 **Forklifts**—The configuration of forklift mechanisms and forklift truck cabs shall permit the operator to have direct view of the tips of the forks in all typical modes of material loading and in all likely operator positions.

50.6 **Heating and Ventilation:**

50.6.1 **Heating**—The crew compartments shall be provided with a heating system capable of maintaining temperatures above 20°C (68°F) during occupancy when personnel are not wearing arctic clothing and exposure is for extended duration (that is, more than 3 h). When arctic clothing is worn, cab heaters shall be capable of maintaining a reference temperature of not less than 5°C (41°F) at the minimum ambient design temperature with the vehicle moving at two-thirds maximum speed and the defrosters operating at maximum capacity. The reference temperature is measured 610 mm (24 in.) above the seat reference point of each operator/passenger position. Air temperatures around any part of the operator/passenger’s body shall not vary more than ±5°C (±9°F). The heater shall achieve these requirements within 1 h after it is turned on.

50.6.2 **Ventilation**—Outside fresh air shall be supplied at minimum rate of 0.57 m³ (20 ft³)/min/person. Air flow rates for hot-climate operation (temperatures above 32°C (90°F)) shall be maintained between 4.2 and 5.7 m³ (150 and 200 ft³)/min/person, unless air conditioning or individual (microclimate) cooling is provided. Air velocity at each person’s head location shall be adjustable either continuously or with not less than three settings (OFF, LOW, and HIGH) from near zero to at least 120 m (400 ft)/min.

50.6.3 **Visibility**—The heating-ventilating system shall be designed to minimize degradation of visibility as a result of frosting or misting of the wind shield.

50.7 **Cranes, Materials, Handling, and Construction:**

50.7.1 **General**—Positioning of equipment and loads shall be facilitated through use of center-of-gravity identification, matching guidelines, identification of attaching points, detachable probes, and so forth. Latches on control levers shall not cause delay in operation.

50.7.2 **Control Labels**—All controls used with lifting equipment shall be labeled as to function and direction of movement.

50.7.3 **Control Placement**—The placement of controls shall be within easy reach of the operator and shall afford optimum visibility of the load at all times.

50.7.4 **Foot-Operated Controls**—Foot-operated controls shall not be selected for precise adjustments or movements. Foot-operated brake pedals that require locking shall lock by foot action alone. For ease of operation, the pedals shall rise from the depressed position in a backward as well as vertical movement.

50.7.5 **Load Capacity**—The load capacity shall be indicated on the equipment, and audible warning devices shall be provided where necessary to indicate that the allowable load is being exceeded.

50.7.6 **Visibility**—Maximum, unobstructed view of the work, including the point sheaves of the basic boom of a revolving crane at a 3-m (10-ft) radius shall be visible to suitably clothed and equipped users with relevant body dimensions varying between fifth and ninety-fifth percentiles.

50.7.7 **Handholds and Footholds**—Suitable handholds and footholds shall be provided to facilitate personnel access and movement.
51. Hazards and Safety

51.1 General—As a part of system equipment design, safety factors shall be given major consideration, including, as a minimum, the effective application of the human engineering criteria in other sections of this practice, together with the representative safety criteria herein.

51.1.1 Principles of Human Behavior Related to Safety—There are principles of human behavior that are of importance to the designer striving to design safe equipment. Armed with this knowledge the designer can design out many of the accidents that occur with shipboard equipment.

51.1.1.1 If the equipment is insufficient, it will be modified by the user, usually at the job site and often with built-in hazards.

51.1.1.2 The operational/maintenance procedures must be clean, definite, and comprehensive, otherwise they will be ignored.

51.1.1.3 Equipment design must be such that it encourages safe use, that is, do not provide hardware that can be used in an unsafe manner.

51.1.1.4 If the equipment or system is not designed to operate as the user’s cultural expectancies and stereotypes lead him or her to think it will operate, he or she will eventually make a mistake.

51.1.1.5 If an unsafe design is allowed in the equipment, no warning note in a technical manual can eliminate it completely. Neither can regular or even special training prevent accidents, even if it mandatory.

51.1.1.6 Equipment users tend to be unimaginative; they do not visualize the consequences of unsafe acts. Therefore, do not expect that an obviously dangerous task will be recognized by the user.

51.1.1.7 Designers shall consider the possibilities for errors and design equipment so incorrect use (deliberate or accidental) will do as little harm as possible.

51.1.1.8 People make guesses as to what a label, instruction, operational chart, and so forth, says if it is not complete, legible, and readable. Be sure that they are complete and legible.

51.1.1.9 If procedures for safe operation or maintenance seem needlessly difficult or burdensome, people avoid doing what is necessary for safety. So, make it easier to use safely than to use it unsafely.

51.1.1.10 Equipment develops a reputation among users and maintainers regarding its difficulty or hazardous use that can significantly affect the way it is used and serviced.

51.1.1.11 Abbreviated checklists tend to cause mistakes so make job procedures detailed enough so the user does not have to fill in the blanks.

51.1.1.12 People must be protected against themselves. Designers cannot create an unsafe piece of equipment or system and expect the user to look out for himself or herself.

51.1.1.13 An operator’s care in using and maintaining an item tends to increase in relation to the item’s cost and complexity. Thus, complicated and costly pieces of equipment, with safety hazards, will usually produce fewer accidents as a result of poor maintenance than will the simpler and less expensive equipment.

51.1.1.14 Ease of maintenance affects the equipment’s reliability.

51.1.1.15 Equipment is particularly susceptible to misuse if operators must communicate with each other to use it.

51.2 Safety Labels and Placards:

51.2.1 Hazard-Identifying Plates—All hazard plates (that is, danger, caution) shall comply with Section 28 and shall be mounted adjacent to any equipment that presents a hazard to personnel (from high voltage, heat, toxic vapors, explosion, ionizing radiation, and so forth) or equipment.

51.2.2 Center of Gravity and Weight—Where applicable, the center of gravity and the weight of equipment shall be distinctly marked.

51.2.3 Weight Capacity—The weight capacity shall be indicated on stands, hoists, lifts, jacks, and similar weight-bearing equipment, to prevent overloading.

51.2.4 Identification of Protective Areas—Areas of operation or maintenance in which special protective clothing, tools, or equipment are necessary (insulated shoes, gloves, suits, and so forth) shall be specifically identified.

51.2.5 NO-STEP Markings—NO-STEP markings shall be provided when necessary to prevent injury to personnel or damage to equipment.

51.2.6 Electrical Labels—All receptacles shall be marked with their voltage, phase, and frequency characteristics, as appropriate.

51.2.7 Hand Grasp Areas—Hand grasp areas shall be conspicuously and unambiguously identified on the equipment.

51.3 Pipe, Hose, and Tube Line Identification—Pipe, hose, and tube lines for liquids, gas, steam, and so forth, shall be clearly and unambiguously labeled or coded as to contents, pressure, heat, cold, or other specific hazardous properties.

51.4 General Workspace Hazards:

51.4.1 Alerting Device—A hazard-alerting device shall be provided to warn personnel of impending danger or existing hazards. Normally, a flashing red light and siren (if an auditory signal is used) are used for the worst condition (DANGER) while a horn and amber light are used for the CAUTION condition.

51.4.2 Emergency Doors and Exits—Emergency doors and exits shall be constructed so that they:

51.4.2.1 Are simple to operate,
51.4.2.2 Are directly accessible,
51.4.2.3 Are unobstructed,
51.4.2.4 Are simple to locate and operate in the dark,
51.4.2.5 Are quick opening in 3 s or less,
51.4.2.6 Require 44 to 133 N (10 to 30 lbs) of operating force to open, and
51.4.2.7 Do not themselves, or in operation, constitute a safety hazard. Two exits, doors, or kickout panel, shall be provided in any manned space where fuel, chemicals, or other flammable materials are used.

51.4.3 Stairs—Stairs, including incline, step risers, and treads, shall conform with standard safe design practice. Incline ladders shall have a maximum angle of 60°, 50° preferred. Skid-proof flooring, stair, and step treads shall be...
provided. Where conditions warrant special precaution, surfaces shall be covered with a non-slip coating. Incline ladders shall run fore and aft.

51.4.4 Obstructions—Workspace around areas where heavy manual maintenance is performed shall be free of obstructions that could cause injury to personnel, either through accidental contact with the obstruction or because the obstruction requires an awkward or dangerous body position.

51.4.4.1 Pipe Hangers—Pipe hangers shall not protrude from the overhead into the minimum head room. Hangers used to support pipe mounted on bulkheads or other locations where they can be struck by passing crew members shall be of the U type and installed, as close as possible, to that shown in Fig. 89 (lower drawing).

51.4.4.2 Storage Racks—Storage racks located in passageways for gas bottles, casualty cables, fire-fighting equipment, and so forth, shall not impede traffic flow and shall not have securing nut studs or other sharp objects protruding into the passageway.

51.4.4.3 Door Swing—Hinges for doors on lockers, electrical cabinets, storage bins, and so forth, shall be located so that a partial or fully opened door will not interfere with personnel and equipment flow.

51.5 Illumination—Adequate illumination shall be provided in all areas. Hazard-identifying plates, stairways, and all hazardous areas shall be illuminated in accordance with the recommended levels of Table 32.

51.6 Thermal Contact Hazards—Equipment that, in normal operation, exposes personnel to surface temperatures greater or less than those shown in Table 48, shall be appropriately guarded. Surface temperatures induced by climatic environment are exempt from this requirement. Cryogenic systems shall also be appropriately guarded.

51.7 General Equipment-Related Hazards:

51.7.1 Interlocks and Alarms—The operation of switches or controls that initiate hazardous operations (ignition, movement of a crane, and so forth) shall require the prior operation of a related or locking control. Where practicable, the critical position of such a control shall activate a visual and auditory warning device in the affected work area.

51.7.2 Access—Units shall be so located and mounted that access to them can be achieved without danger to personnel from electrical charge, heat, moving parts, chemical contamination, radiation, or other hazards. Mounting heights for common electrical fixtures shall be in accordance with Fig. 117.

51.7.3 Hazardous Access—Where access areas must be located over dangerous mechanical or electrical components, the access door or cover shall be designed to actuate an internal light when opened, and a highly visible warning label shall be provided on the outside of the door or cover.

51.7.4 Edge Rounding—Where applicable, all exposed edges and corners shall be rounded to a minimum of 0.76-mm (0.03-in.) radius. Sharp edges and corners that present a personal safety hazard or potential damage to equipment during usage shall be suitably protected or rounded to a minimum radius of 13 mm (0.5 in.).

51.7.5 Storeroom Shelves—Shelves in storerooms over 203 mm (80 in.) above the deck shall be equipped with foot supports (lower shelves are acceptable) designed to support a 113-kg (250-lbs) load. Where lower shelves are used as a foot support, they shall be designed to support whatever may be stored on the shelf plus a 113-kg (250-lbs) load.

51.7.6 Eyewash Fountains—A minimum clearance of 30 cm (12 in.), and 48 cm (15 in.) preferred, shall be provided on either side of an eyewash fountain as measured from the fountain centerline.

51.8 Platforms:

51.8.1 Locks—Self-locking or other fail-safe devices shall be incorporated on elevating stands, work platforms, and drawbridges to prevent accidental or inadvertent collapsing or falling.

51.8.2 Handrails, Safety Bars, and Chains—Handrails, safety bars, or chains shall be installed around platforms and across stair or step openings in platforms, ledges, catwalks, and so forth. Such guards shall be placed 107 cm (42 in.) above the standing surface. An intermediate guard rail shall be provided. Chains shall only be used where it is not feasible to install handrails or safety bars. Kickboards, at least 152 mm (6 in.) high, shall be installed. When platforms are raised and located near a railing (for example, signal lights on the bridge wings), the railing around the platform must also be raised to maintain the 107-cm (42-in.) height.

51.8.3 Safety Mesh—Screen or safety mesh shall be installed on the underside of open gratings, platforms, or flooring surfaces where there is a possibility that small tools, parts, or debris may fall through the grating on workers or equipment beneath the platform.

51.8.4 Elevated Work Platforms—Elevated work platforms raised by electric or hydraulic motors shall fail safe so that in the event power or hydraulic failure occurs the platform will lock in the up position. All platforms shall have their lifting capacity clearly marked on the platform.

51.9 Electrical Hazards:

51.9.1 Shock—The principle electrical hazard is shock. All electrical potentials of 30-V rms or more are potential shock hazards. Most shock deaths result from contacting relatively low potentials, ranging from 70 to 500 V. Table 49 summarizes typical effects of various currents.

51.9.2 Shock Prevention—One or more of the following shall be used to minimize the chance of inadvertent contact

---

**TABLE 48 Temperature Limits**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Metal</th>
<th>Glass</th>
<th>Plastic or Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C (°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Momentary contact</td>
<td>60</td>
<td>68</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>(140)</td>
<td>(154)</td>
<td>(185)</td>
</tr>
<tr>
<td>Prolonged contact</td>
<td>49</td>
<td>59</td>
<td>69</td>
</tr>
<tr>
<td>or handling</td>
<td>(120)</td>
<td>(138)</td>
<td>(156)</td>
</tr>
<tr>
<td>Momentary contact</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>or handling</td>
<td>(32)</td>
<td>(32)</td>
<td>(32)</td>
</tr>
<tr>
<td>Prolonged contact</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>or handling</td>
<td>(32)</td>
<td>(32)</td>
<td>(32)</td>
</tr>
</tbody>
</table>
with live electrical wires, potentials, exposed contacts, charged capocetone, and so forth.

51.9.2.1 Guards.

51.9.2.2 Grounding.

51.9.2.3 Interlock Switches—Every door or access part that provides access to high-voltage potentials shall have an interlock.

51.9.2.4 Warning Signs.

51.9.2.5 Capacitor Discharge Devices (Bleeders) shall discharge the capacitor fully in 1 min or less.

51.9.2.6 Fuses.

51.9.3 Insulation of Tools—Tools and test leads to be used near high voltages shall be adequately insulated.

51.9.4 Plugs and Receptacles—Plugs and receptacles shall be designed so that a plug of one voltage rating cannot be inserted into a receptacle of another rating.

51.9.5 Voltage Exposure—Equipment shall be designed so that all hot contacts will be socket contacts.

51.9.6 Ground Potential—Equipment shall be designed so that all external parts, with the exception of antenna and transmission line terminals, will be at ground potential.

51.9.7 Electrically Operated Hand Tools—Electrically operated hand-held power tools shall be designed with three-wire power cords with one wire at ground potential and shall have exposed surfaces that are either nonconducting or are electrically connected to the ground wire. Exposed surfaces include cases, grips, handles, switches, triggers, chucks, and other surfaces that are capable of being contacted during operation. Portable tools, protected by an approved system of double insulation or its equivalent, may be used without a ground wire when approved by the procuring activity. Hand tools with the potential for injury to personnel (for example, deck sanders, large drills, and so forth) shall be equipped with a dead man power switch.

51.9.8 Vehicle Batteries—All batteries that have a rating greater than 25 amp hours shall have terminal guarding to prevent inadvertent short-circuit. Such guarding shall also prevent short-circuiting of the battery in spite of clearly improper but possible acts by personnel, such as placing of tools across terminals, resting a heavy object on the battery cover, and standing on a battery cover.

51.9.9 Main Power Switch—Every item of equipment shall have a clearly labeled main-power switch that turns off all power to the item.

51.10 Mechanical Hazards:

51.10.1 Guards—A guard shall be provided on all moving parts of machinery and transmission equipment, including pulleys, belts, gears, blades, and so forth, on which personnel may become injured or entangled. Where perforations are provided in guards for air circulation, none shall be larger than a 13-mm (0.5-in.) round or square hole.

51.10.2 Steps and Ladders—Adequate clearance for fingers shall be provided in the design of telescoping steps or ladders.

51.11 Fluid Hazards:

51.11.1 Connectors—Each connector used in the handling or control of hazardous fluids, including propellants, solvents, toxics, hypergolics, asphyxiants, and so forth, shall be incompatible with other connectors within the access area of that conductor.

51.11.2 Fluid and Fuel-Servicing Equipment—Automatic shutoff devices shall be provided on fluid and fuel service equipment to prevent overflow and spillage.

51.11.3 Flammable Liquid Lockers—Flammable liquid lockers shall not be installed nearer than 1.8 m (6 ft) to a door or exit if it is the only means of egress from the space or compartment.

51.12 Barriers—Barriers may be used to protect a person from contacting a hazard (for example rotating machinery,
electrical contact, hot pipe). The required height of the barrier and the distance separating the barrier from the hazard depends on the height of the hazard as shown in Fig. 118.

51.13 Toxic Hazards:
51.13.1 Toxic Fumes:
51.13.1.1 General—All reasonable precautions shall be taken to eliminate toxic fume hazards. From the standpoint of practical health-hazard control, the most important constituents are carbon monoxide from gasoline engines, aldehydes, nitrogen oxides from diesel engines, and sulfur dioxide from marine turbine engines.

(a) Carbon Monoxide—Carbon monoxide in personnel areas shall be reduced to the lowest level feasible. Personnel shall not be exposed to concentrations of carbon monoxide (CO) in excess of values which will result in carboxyhemoglobin (COHb) levels in their blood greater than the following percentages: 5% COHb (all system design objectives and aviation system performance limits) and 10% COHb (all other systems performance limits).

51.13.1.2 Allowable Limits—Allowable limits for some of the toxic gases described above are shown in Table 50.

51.13.2 Toxic Material—Place all storage bins containing toxic material (for example, soaps, bleach, and so forth, in the laundry) in a vertical position if possible. If mounted horizontally, the bins shall be no higher than 151 cm (60 in.) above the deck.

There should be no interpolation of the values in the table, see the following examples:

**Example 1**

The height of the danger point, "A", is 1500 mm (59.1 in) and its horizontal distance, "C", from the proposed barrier is 700 mm (27.6 in). Using the table, the height of the barrier, "B", should be 1800 mm (71.1 in).

**Example 2**

The height of the barrier, "B", is 1300 mm (51.2 in) and the height of the danger point, "A", is 2300 mm (90.6 in). Using the table, the barrier should be positioned 600 mm (23.6 in) from the danger point.

**Example 3**

The height of the barrier, "B", is 1700 mm (66.9 in) and the horizontal distance, "C", from the danger point is 550 mm (21.7 in). Using the table, the danger point should not be between 1200 and 2200 mm (47.2 and 86.8 in).

<table>
<thead>
<tr>
<th>Distance of danger point from floor &quot;A&quot; mm (in)</th>
<th>2400</th>
<th>2200</th>
<th>2000</th>
<th>1800</th>
<th>1600</th>
<th>1400</th>
<th>1200</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>(94.7)</td>
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<td></td>
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<td>(86.8)</td>
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<td>(78.9)</td>
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<td>(71.1)</td>
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<td>(47.4)</td>
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<td>(18.8)</td>
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<tr>
<td>(12.0)</td>
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<td>(7.9)</td>
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</tr>
</tbody>
</table>

**FIG. 118 Required Distance Between Hazard and Barrier**
51.14 Radiation—Radiation-emitting systems and equipment require special consideration to minimize hazards to operators and maintenance personnel. Ionizing radiation exposure rates produced by any device shall not exceed 0.5 mR/h at a distance of 50 mm (2 in.) from any point on the external surface.

52. User-Computer Interface

52.1 General—Computer programs and equipment interfaces shall provide a functional interface between the system for which they are designed and users (operators/maintainers) of that system. This interface shall optimize compatibility with personnel and shall minimize conditions that can degrade human performance or contribute to human error.

52.1.1 Standard Procedures—Users shall be provided standard procedures for similar, logically related transactions.

52.1.2 Computer Response—Every input by a user shall consistently produce some perceptible response output from the computer.

52.1.3 On-Line Guidance—Users shall be provided on-line data and command indices and dictionaries to guide selection and composition for data and command entries. Definitions of allowable options, system capabilities, procedures, and ranges of values shall be displayable at the user’s request.

52.1.4 System Status—Users shall be provided information at all times on system status regarding operational modes, availability, and loads, either automatically or by request.

52.1.5 Log-On Procedures—In applications in which users must log on to the system, log on shall be a separate procedure that must be completed before a user is required to select among any operational options.

52.1.5.1 Automatic Log-On Display—Appropriate prompts for log on shall be automatically displayed on the user’s terminal with no special action required other than turning on the terminal.

52.1.5.2 Log-On Feedback—Users shall be provided feedback relevant to the log-on procedure that indicates the status of the inputs.

52.1.5.3 Log-On Delay—If a user cannot log on to a system, a prompt shall be explained to provide the reason for this inability. Log-on processes shall require minimum input from the user consistent with the requirements prohibiting illegal entry.

52.1.6 Log-Off Procedures—When a user signals for log off, the system shall check pending transactions to determine if data loss seems probable. If so, the computer shall prompt for confirmation before the log-off command is executed.

52.1.7 Computer Failure—In the event of partial hardware/software failure, the program shall allow for orderly shutdown and establishment of a checkpoint so restoration can be accomplished without loss of computing performed to date.

52.1.8 Interaction—Where two or more users may access the computer program or data processing results from multiple personnel-equipment interfaces, the operation by one person shall not interfere with the operations of another person unless mission survival may be contingent upon the preemption. Provisions shall be made so that the preempted user can resume operations at the point of interference without information loss.

52.2 Data Entry:

52.2.1 General—Data entry functions shall be designed to establish consistency of data entry transactions, minimize input actions and memory load on the user, ensure compatibility of data entry with data display, and provide flexibility of user control of data entry.

52.2.2 User Pacing Manual—Data entry shall be paced by the user, depending on the user’s application, criticality of the operation and attention span, rather than by the system.

52.2.3 Positive Feedback—The system shall provide a positive feedback to the user of the acceptance or rejection of a data entry.

52.2.4 Processing Delay—Where system overload or other system conditions will result in a processing delay, the system shall acknowledge the data entry and provide an indication of the delay to the user.

52.2.5 Explicit Action—Data entry shall require an explicit completion action, such as the depression of an ENTRY key.

52.2.6 Validation—Data entries shall be validated by the system for correct format, legal value, or range of values. Where repetitive entry of data sets is required, data validation for each set shall be completed before another transaction can begin.

52.2.7 Software Available Data—The user shall not be required to enter data already available to the software.

52.2.8 Input Units—Data shall be entered in units that are familiar to the user.

52.2.9 Cursors:

52.2.9.1 Control—Systems using cursors shall provide cursor control capability consistent with user speed and accuracy requirements.

52.2.9.2 Display—A movable cursor within the display shall have a distinctive visual attribute that does not obscure other displayed entities. When fine positioning accuracy is required, as in some forms of graphic and image-processing applications, the displayed cursor shall include an appropriate point designation feature (such as crosshairs).

52.2.9.3 Home Position—The home position for the cursor shall be consistent across similar types of displays.

52.2.9.4 Explicit Actuation—A separate, explicit action, distinct from cursor position, shall be required for the actual entry (for example, enabling, actuation) of a designated position.

52.2.9.5 Consistent Positioning—Where cursor positioning is incremental by discrete steps, the step size of cursor movement shall be consistent horizontally (that is, in both right and left directions) and vertically (in both up and down directions).
52.2.9.6 Keyboard Cursor Control—When position designation is required in a task emphasizing keyed data entry, cursor control shall be by some device integral to the keyboard. If cursor movement is accomplished by depressing keys, the keys shall be located on the main keyboard.

52.2.9.7 Movement Relationships—The response of a cursor to control movements shall be consistent, predictable, and compatible with the user’s expectations. For cursor control by key action, a key labeled with a left-pointing arrow shall move the cursor leftward on the display; for cursor control by joystick, leftward movement of the control shall result in leftward movement of the cursor.

52.2.9.8 Abbreviations, Mnemonics, and Codes—When abbreviations, mnemonics, or codes are used to shorten data entry, they shall be distinctive and have a relationship or association to normal language or specific job-related terminology.

52.2.9.9 Explicit Delete Action—Data deletion or cancellation shall require an explicit action, such as the depression of a DELETE key.

52.2.9.10 Change of Data—Where a user requests change (or deletion) of a data item that is not currently being displayed, the option of displaying the old value before confirming the change shall be presented.

52.2.9.11 Single Method of Data Entry—Data entry methods and data displays shall not require the user to shift between entry methods.

52.2.9.12 Data Entry Display—Where data entry on an electronic display is permitted only in prescribed areas, a clear visual definition of the entry fields shall be provided.

52.3 Keyboard:

52.3.1 Use—A keyboard shall be used to enter alphabetic, numeric, and other special characters into the system.

52.3.2 Timely Display—Keyed inputs, except security items such as passwords, shall be echoed on the display within 0.1 s.

52.3.3 Length—Except for extended text, the length of individual data items shall be minimized.

52.3.4 Justification—When entering tabular data, the user shall not be required to right- or left-justify tabular data entries. The system shall automatically justify columnar data with respect to decimal point, left margin, and right margin.

52.3.5 Numeric Keypads—Keyboards used in systems requiring substantial numeric input shall be equipped with a numeric keypad.

52.3.6 Minimization of Keying—The amount of keying required shall be minimized by using numbered lists and abbreviations.

52.3.7 Minimization of Shift Keying—The use of key-shifting functions shall be minimized during data entry transactions.

52.3.8 Data Change—In keyed data entry, means shall be provided to allow users to change previous entries, if necessary, by DELETE and INSERT actions.

52.4 Fixed Function (Dedicated) Keys:

52.4.1 Use—Fixed function keys (for example, ENTER) shall be used for time-critical, error-critical, or frequently used control inputs.

52.4.2 Standardization—Fixed function keys shall be common throughout the system.

52.4.3 Functional Consistency—Once a key has been assigned a given function, it shall not be reassigned to a different function for a given user.

52.4.4 Availability—Fixed function keys shall be selected to control functions that are continuously available; lockout of fixed function keys shall be minimized.

52.4.5 Nonactive Keys—Nonactive fixed function keys shall be replaced by a blank key on the keyboard.

52.4.6 Grouping—Fixed function keys shall be logically grouped and shall be placed in distinctive locations on the keyboard.

52.4.7 Activation—A fixed function key shall require only a single actuation to accomplish its function.

52.4.8 Feedback—When fixed function key activation does not result in an immediately observable natural response, the user shall be given an indication of system acknowledgement.

52.4.9 Function Labels—Key assignments shall be displayed at all times, preferably through direct marking. Where abbreviations are necessary, they shall be in accordance with Section 28.

52.5 Variable Action Keys:

52.5.1 Use—Variable action keys may be used for programmable menu selection and entry of control functions.

52.5.2 Status Display—When the effect of an action key varies, the status of the key shall be displayed.

52.5.3 Reprogrammable or Inactive Default Action—When keys with labeled default functions are reprogrammed or turned off, a visual warning shall alert the user that the standard action is not currently accessible via that key.

52.5.4 Relabeling—Provision shall be made for easily relabeling variable action keys. Labels for variable function keys, located along the perimeter of a display, may be generated on the display face.

52.5.5 Shifted Characters—Variable function keys shall not be shifted character keys that require the depression of a shift key before each actuation of the variable key.

52.5.6 Easy Return to Base-Level Functions—Where the functions assigned to a set of function keys change as a result of user selection, the user shall be given an easy means to return to the initial, base-level functions. For example, in cockpit design, where multifunction keys may be used for various purposes such as navigation or weapons control, the aircrew should be able to take a single action to restore those keys quickly to their basic flight control functions.

52.5.7 Minimization of Keying—Operational sequences using variable action keys shall be minimized with respect to the number of key functions required.

52.6 Lightpen:

52.6.1 Use—A lightpen may be used when noncritical, imprecise input functions are required. Such direct-pointing controls shall be used when item selection is the primary type of data entry.

52.6.2 Dimensions and Mounting—See 26.6.3.
52.6.3 Actuation—Lightpens shall be equipped with a discrete actuating/deactuating mechanism. For most applications, a push-tip switch, requiring 0.5 N (2 to 5 oz) of force to actuate, is preferred.

52.6.4 Feedback—Two forms of feedback shall be provided to the user when using a lightpen:

52.6.4.1 Feedback concerning lightpen placement, preferably in the form of an illuminated circle projected from the lightpen onto the display screen, and

52.6.4.2 Feedback that the lightpen has actuated and the input has been received by the system.

52.7 Joystick/Trackball:

52.7.1 Use—A joystick, trackball, or similar device may be used when precise input functions are required. These devices shall conform to 26.2, 26.3, 26.4, 26.5, and 26.6.

52.7.2 Actuation/Deactuation—A discrete mechanism shall be provided to allow the user to actuate/deactuate the device.

52.8 Touch Screen—See 26.8 for information on touch screens.

53. Data Display

53.1 Display Format:

53.1.1 Consistency—Display formats shall be consistent within a system.

53.1.1.1 When appropriate for users, the same format shall be used for input and output.

53.1.1.2 Data entry formats shall match the source document formats.

53.1.1.3 Essential data, text, and formats shall be under computer, not user, control.

53.1.2 Criticality—Only data essential to the user’s needs shall be displayed.

53.1.3 Readily Usable Form—Data presented to the user shall be in a readily usable and readable form that the user does not have to transpose, compute, interpolate, or mentally translate into other units, number bases, or languages.

53.1.4 Order and Sequences—When data fields have a naturally occurring order (such as chronological), such order shall be reflected in the format organization of the fields.

53.1.4.1 Data Grouped by Importance—Where some displayed data items are of significant importance or require immediate user response, those items shall be grouped at the top of the display.

53.1.4.2 Data Grouped by Function—Where sets of data are associated with particular questions or related to particular functions, each set may be grouped together to help illustrate those functional relationships.

53.1.4.3 Data Grouped by Frequency—Where some data items are used more frequently than others, those items may be grouped at the top of the display.

53.1.5 Data Separation—Separation of groups of information shall be accomplished by blanks, spacing, lines, color coding, or other means consistent with the application.

53.1.6 Recurring Data Fields—Recurring data fields within a system shall have consistent names and shall have consistent relative position within displays.

53.1.7 Extended Alphanumeric—When five or more alphanumeric characters within natural organization are displayed, the characters shall be grouped in blocks of three to five characters within each group separated by a minimum of one blank space or other separating character such as a hyphen or slash.

53.1.8 Comparative Data Fields—Data fields to be compared on a character-by-character basis shall be positioned one above the other.

53.1.9 Labels and Titles—Each display shall be labeled with a title or label that is unique within the system. To make the display as meaningful as possible and to reduce user memory requirements, every field or column heading shall be labeled.

53.1.9.1 Display Title—Every display shall begin with a title or header at the top, describing briefly the contents or purpose of the display. There shall be at least one blank line between the title and the body of the display.

53.1.9.2 Command Entry, Prompts, Messages at Bottom—The last several lines at the bottom of every display shall be reserved for status and error messages, prompts, and command entry.

53.1.10 Data Group Labels—Each individual data group or message shall contain a descriptive title, phrase, word, or similar device to designate the content of the group or message. Labels shall perform the following:

53.1.10.1 Be located in a consistent fashion adjacent to the data group or message they describe. The relationship of the label to the group, field, or message being described shall be unambiguous.

53.1.10.2 Be highlighted or otherwise accentuated to facilitate operator scanning and recognition. The technique used to accentuate labels shall be different from, and easily distinguished from, that used to highlight or code emergency or critical messages.

53.1.10.3 Be unique and meaningful to distinguish them from data, error messages, or other alphanumericcs.

53.1.10.4 Be displayed in uppercase only, while text may be displayed in uppercase and lowercase.

53.1.10.5 Reflect the question or decision being posed to the user, when presenting a list of user options.

53.1.11 Scrolling—Items continued on the next page (scrolled) shall be numbered relative to the last item on the previous page.

53.1.12 Page Numbering—Each page of a multiple-page display shall be labeled to identify the currently displayed page and the total number of pages, for example, Page 2 of 5.

53.1.13 Frame Identification—Every display frame shall have a unique identification to provide a reference for use in requesting the display of that frame. The frame identification shall be an alphanumeric code or an abbreviation which is prominently displayed in a consistent location. It shall be short enough (three to seven characters) and meaningful enough to be learned and remembered easily.

53.2 Display Content:

53.2.1 Standardization—The content of displays within a system shall be presented in a consistent, standardized manner.

53.2.2 Information Density—Information density shall be held to a minimum in displays used for critical task sequences. A minimum of one-character space shall be left blank vertically
above and below critical information, with a minimum of
two-character spaces left blank horizontally before and after.

53.2.2.1 *Crowded Displays*—When a display contains too
much data for presentation in a single frame, the data shall be
partitioned into separately displayable pages.

53.2.2.2 *Related Data on Same Page*—When partitioning
displays into multiple pages, functionally related data items
shall be displayed together on one page.

53.2.2.3 *Page Labeling*—In a multipage display, each page
shall be labeled to show its relation to the others.

53.2.3 *Abbreviations and Acronyms*—Information shall be
displayed in plain concise text wherever possible. Abbrevia-
tions and acronyms shall conform to Section 28. Abbreviations
shall be distinctive to avoid confusion. Words shall have only
one consistent abbreviation. No punctuation shall be used in
abbreviations. Definitions of all abbreviations, mnemonics, and
codes shall be provided at the user’s request.

53.2.3.1 *Data Entry and Display Consistency*—Data dis-
play word choice, format, and style shall be consistent with the
requirements for data entry and control.

53.2.3.2 *Context for Displayed Data*—The user shall not
have to rely on memory to interpret new data; each data display
shall provide needed context, including recapitulating prior
data from prior displays as necessary.

53.3 *Display Coding*:

53.3.1 *Use*—Coding shall be used to differentiate between
items of information and to call the user’s attention to changes
in the state of the system. Coding shall be used for critical
information, unusual values, changed items, items to be
changed, high priority messages, special areas of the display,
errors in entry, criticality of command entry, and targets.
Consistent, meaningful codes shall be used. Coding shall not
reduce legibility or increase transmission time.

53.3.2 *Flash*—Flash coding shall be used to call the user’s
attention to mission critical events only. No more than two
flash rates shall be used. Where one rate is used, the rate shall
be between three and five flashes per second. Where two rates
are used, the second rate shall be less than two per second.

53.3.3 *Brightness*—Brightness intensity coding shall be
used only to differentiate between an item of information and
adjacent information. No more than three levels of brightness
shall be used. Each level shall be separated from the nearest by
at least a 2:1 ratio.

53.3.4 *Pattern and Location*—Pattern and location coding
shall be used to reduce user search time by restricting the area
to be searched to prescribed segments.

53.3.5 *Underlining*—Underlining may be used to indicate
unusual values, errors in entry, changed items, or items to be
changed.

53.3.6 *Symbol*—Symbol coding may be used to enhance
information assimilation from data displays. Symbols shall be
analogous of the event or system element they represent or be in
general use and well known to the expected users. Where size
difference between symbols is used, the major dimensions of
the larger shall be at least 150% of the major dimension of the
smaller with a maximum of three size levels permitted.

53.3.6.1 *Special Symbols*—When special symbols are used
to signal critical conditions, they shall be used for only that
purpose.

53.3.6.2 *Markers Close to Words Marked*—When a special
symbol is used to mark a word, the symbol shall be separated
from the beginning of the word by one space.

53.3.7 *Color*—Color coding may be used to differentiate
between classes of information in complex, dense, or critical
displays. Information shall not be coded solely by color if the
data must be accessed from monochromatic as well as color
terminals or printed in hardcopy versions.

53.3.8 *Shape*—Shape coding may be used for search and
identification tasks.

53.3.9 *Brightness Inversion*—When a capability for bright-
ness inversion is available (so-called “reverse video,” where
dark characters on a bright background can be changed under
computer control to bright on dark or vice versa), it may be
used for highlighting critical items that require user attention.
When used for alerting purposes, brightness inversion shall be
reserved consistently for that purpose and not be used for
general highlighting.

53.4 *Dynamic Displays*:

53.4.1 *Changing Values*—Changing alphanumeric values
that the operator must reliably read shall not be updated more
than once per second. Changing values that the viewer uses to
identify rate of change or to read gross values shall not be
updated faster than five times per second, nor slower than
twice second, when the display is to be considered as real time.

53.4.2 *Update Rate*—The rate of update shall be control-
able by the user and shall be determined by the use to be made
of the information.

53.4.3 *Display Freeze*—A display freeze mode shall be
provided to allow close scrutiny of any selected frame that is
updated or advanced automatically by the system. For frozen
display frames, an option shall be provided to allow resump-
tion at the point of stoppage or at the current real-time point.

53.4.4 *Freeze Feedback*—An appropriate label shall be
provided to remind the operator when the display is in the
freeze mode.

53.5 *Tabular Data*:

53.5.1 *Use*—Tabular data displays shall be used to present
row-column data.

53.5.2 *Standard Formats*—Location of recurring data shall
be similar among all tabular data displayed and common
throughout the system.

53.5.3 *Arrangement*—Tabular data shall be displayed in a
left-to-right, top-to-bottom array. Alphanumeric data shall be
left justified; numeric data shall be right justified with decimal
points, if any, aligned vertically.

53.5.4 *Titles*—When tabular data are divided into classifi-
cations, the classification titles shall be displayed and subclassi-
fication shall be identified. When tabular data extend over
more than one page vertically, the columns shall be titled
identically on each page.

53.5.5 *Horizontal Extension*—Tabular displays shall not
extend over more than one page horizontally.
53.5.6 Lists—Items in lists shall be arranged in a recognizable order, such as chronological, alphabetical, sequential, functional, or importance.

53.5.6.1 List Lines—Each item in a list shall start on a new line.

53.5.6.2 Vertical Extension—Where lists extend over more than one display page, the last line of one page shall be the first line of the succeeding page.

53.5.6.3 Marking Multiline Items in a List—Where a single item in a two separate word list continues for more than one line, such items shall be marked in some way (for example, blank line, indentation) so that the continuation of the item is obvious.

53.5.6.4 Arabic Numerals—When listed items will be numbered, Arabic numerals shall be used rather than Roman.

53.5.6.5 Vertical Ordering in Multiple Columns—Where items in a list are displayed in multiple columns, items shall be ordered vertically within each column.

53.5.6.6 Hierarchic Structure for Long Lists—Where lists are long and must extend beyond more than one displayed page, a hierarchic structure shall be used to permit the logical partitioning into related shorter lists.

53.5.7 Numeric Punctuation—Long numeric fields shall not be punctuated with spaces, commas, or slashes. Conventional punctuation schemes shall be used if in common usage. Where none exist, a space shall be used after every third or fourth digit. Leading zeros shall not be used in numerical data except where needed for clarity.

53.5.8 Alphanumeric Grouping—Strings of alphanumericics shall be grouped into sets of three to five characters or grouped at natural breaks. When a code consists of both letters and digits, common character types shall be grouped for ease of location.

53.5.9 Distinctive and Informative Labels—Rows and columns shall be labeled distinctively to guide data entry.

53.5.10 Justification of Numeric Entry—Users shall be allowed to make numeric entries in tables without concern for justification; the computer shall right justify integers or else justify with respect to a decimal point if present.

53.5.11 Labeling Units of Measurement—In tabular display, the units of displayed data shall be consistently included in the column labels.

53.5.12 Consistent Column Spacing—Column spacing within a table from one table to another shall be uniform and consistent.

53.5.13 Column Scanning Cues—A column separation of at least three spaces shall be maintained.

53.5.14 Row Scanning Cues—In dense tables with many rows, a blank line shall be inserted after a group of rows at regular intervals. No more than five lines shall be displayed without a blank line being inserted.

53.6 Graphic Displays:

53.6.1 Use—Graphic data displays may be used to present assessment of trend information, spatially structured data, time critical information, or relatively imprecise information.

53.6.2 Recurring Data—See 53.1.6.
target areas on maps, flight plans), templates or skeletal displays shall be provided for those formats to aid data entry.

53.6.16 Computer Deviation of Graphic Data—When graphic data can be derived from data already available in the computer, machine aids for that purpose shall be provided.

53.6.17 Drawing Lines—When line drawing is required, users shall be provided with aids for drawing straight line segments. When line segments must join or intersect, computer aids shall be provided to aid in such connection.

53.6.18 Drawing Figures—When a user must draw figures, computer aids shall be provided for that purpose (for example, templates, tracing techniques, stored forms).

53.6.19 Changing Size—When editing graphic data, users shall be provided with the capability to change the size (scale) of any selected element on the display, rather than delete and recreate the element in a different size.

53.6.20 Highlighting Critical Data—When a user’s attention must be directed to a portion of a graphic display showing critical or abnormal data, that feature shall be highlighted with some distinctive means of data coding.

53.6.21 Reference Index—When a user must compare graphic data to some significant level or critical value, a reference index or baseline shall be included in the display.

53.6.22 Data Annotation—When precise reading of a graphic display may be required, the capability shall be provided to supplement the graphic representation with the actual numeric values.

53.6.23 Normal Orientation for Labels—The labels on dynamic graphic displays shall remain with the top of the label up when the displayed image rotates.

53.6.24 Pictorial Symbols—Pictorial symbols (for example, icons, pictograms) shall look like the objects, features, or processes they represent.

53.6.25 Display of Scale—When a map or other graphic display has been expanded from its normal presentation, an indicator of the scale expansion shall be provided.

53.6.26 Consistent Scaling—When users must compare graphic data across a series of charts, the same scale shall be used for each chart.

53.6.27 Single Scale Only—Where graphs are presented, only a single scale shall be shown in each axis, rather than including different scales for different curves in the graph. If interpolation must be made or where accuracy of reading graphic data is required, computer aids shall be provided the user.

53.6.28 Unobtrusive Grids—When grid lines are displayed, they shall be unobtrusive and shall not obscure data elements. Grid lines shall be displayed or suppressed at the option of the user.

53.6.29 Direct Display of Differences—Where users must evaluate the difference between two sets of data, that difference shall be plotted directly as a curve in its own right, rather than requiring user to compare visually the curves that represent the original data sets.

53.6.30 Bar Graphs—Bar graphs shall be used for comparing a single measure across a set of several entities or for a variable sampled at discrete intervals.

53.6.30.1 Bar Spacing—Adjacent bars shall be spaced closely enough, normally not more than one bar width, so that a direct visual comparison can be made without eye movement.

53.6.30.2 Histograms (Step Charts)—Histograms (bar graphs without spaces between the bars) shall be used where bar graphs are required and where a great many intervals must be plotted.

53.7 Textual Data Displays:

53.7.1 Use—Information, such as abstracts or reports, that cannot be presented in any other format, may be presented in text format.

53.7.2 Formats—Textual data formats shall conform to the practices established for the particular type of textual data displayed.

53.7.3 Paragraph Separation—Text paragraphs shall be separated by at least one blank line. Paragraphs shall be numbered.

53.7.4 Brevity—Short simple sentences shall be used and shall be displayed in normal upper/lowercase font.

53.7.5 Abbreviations—See 52.2.9.8.

54. Text/Program Editing

54.1 Buffer—When inserting characters, words, or phrases (editing), items to be inserted shall be collected in a buffer area and displayed in the prescribed insert area of the screen for subsequent insertion by user command.

54.2 Presentation Mode—Display mode rather than line mode shall be used for text editing.

54.3 Display Window—ROLL and SCROLL commands shall refer to the display window not the text/data, that is, the display window shall appear to the user to be an aperture moving over stationary text.

54.4 Editing Commands—Easy-to-use, special editing commands, such as MOVE, COPY, and DELETE, for adding, inserting, or deleting text/program segments shall be provided.

54.4.1 Text Edit Commands—In text editing, the special commands shall be based on sentences, paragraphs, or higher-order segments.

54.4.2 Program Edit Commands—In program editing, the special commands shall be used on lines or subprograms. Program lines shall reflect a numbering scheme for ease in editing and error correction. When available, line-by-line syntax checking shall be under user control.

54.4.3 Tab Controls—For editing programs or tabular data, cursor tab controls or other provisions for establishing and moving readily from field to field shall be provided.

54.5 Editing Commands—Where editing commands are made by keying onto the display, the editing commands shall be readily distinguishable from the displayed textual material.

54.6 Highlighted Text—Where text has been specified to become the subject of control entries (for example, for underlining, bolding, moving, copying, or deleting), the affected segment of text shall be highlighted to indicate its boundaries.

54.7 String Search—The capability shall be provided to allow the user to specify a string of text (words, phases, or numbers) and request the computer to advance (or back up) the cursor automatically to the next occurrence of that string.
54.8 Automatic Line Break—An automatic line break (carriage return) shall be provided when the text reaches the right margin for entry/editing of unformatted text. User override shall be provided.

54.9 Format Control—An easy means shall be provided for users to specify required format control features during text entry/editing, for example, to specify margins, tab settings, line spacing, and so forth.

54.10 Predefined Formats—When text formats must follow predefined standards, the required format shall be provided automatically. Where text formats are a user option, a convenient means shall be provided to allow the user to specify and store for future use the formats that have been generated for particular applications.

54.11 Frequently Used Text—The capability shall be provided to label and store frequently used text segments (for example, signature blocks, organizational names, call signs, coordinates) and later to recall (copy into current text) stored segments identified by their assigned labels.

54.12 Text Displayed as Printed—Users shall have the option of displaying text as it will be printed, including underlining, boldface, subscript, superscript, special characters, special symbols, and different styles and sizes of type. Where display of all possible features (for example, special fonts) is impractical, format codes shall be highlighted and displayed within the text to mark the text that will be affected by the code.

54.13 Control Annotations—Where special formatting features are indicated in the text by use of special codes or annotation, the insertion of the special annotation shall not disturb the spacing of the displayed text and shall not disturb formatting of graphs and tables or alignment of rows and columns.

54.14 Flexible Printing Options—In printing text, users shall be allowed to select among available output formats (for example, line spacing, character size, margin size, heading, and footing) and to specify the pages of a document to be printed.

54.15 Head and Foot of File—The means shall be provided to readily move the cursor to the head or the foot (end) of the file.

55. Audio Displays, Interface

55.1 Uses—Audio displays (signals), used as part of the user-computer interface, have application where:

55.1.1 The common mode of visual display is restricted by overburdening or user mobility needs and it is desirable to cue, alert, or warn the user, or

55.1.2 The user shall be provided feedback after control actuation, data entry, or completion of timing cycles and sequences.

55.2 Other Requirements—Other audio design criteria apply. See Sections 14, 15.1 and 15.3.

55.3 Supportive Function, Audio—Audio signals used in conjunction with visual displays shall be supplementary to the visual signals and shall be used to alert and direct the user’s attention to the appropriate visual display.

55.4 Signal Characteristics—The intensity, duration, and source location of the signal shall be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal area. Signals shall be intermittent, allowing the user sufficient time to respond. Signals shall be automatically terminated by operator response action or by manual control.

55.5 Frequency—See Section 16.

55.6 Alarm Settings—When alarm signals are established on the basis of user-defined logic, users shall be permitted to obtain status information concerning current alarm settings, in terms of dimensions (variables) covered and values (categories) established as critical. Alarm status information is particularly necessary in monitoring situations in which responsibility may be shifted from one user to another as in changes of shift.

56. Interactive Control

56.1 General—System response times shall be consistent with operational requirements. Required user response times shall be compatible with required system response time. Required user response times shall be within the limits imposed by total user tasking expected in the operational environment.

56.2 Response Time—System response times shall be consistent with operational requirements. Required user response times shall be compatible with required system response time. Required user response times shall be within the limits imposed by total user tasking expected in the operational environment. See Section 56.27, Error Management/Data Protection.

56.2.1 Response Time Induced Keyboard Lockout—If computer processing time requires delay of concurrent user inputs and no keyboard buffer is available, keyboard lockout shall occur until the computer can accept the next transaction. An alert shall be displayed to indicate to the user that lockout has occurred.

56.2.2 Keyboard Restoration—When the computer is ready to continue, following response time-induced keyboard lockout, a signal to so indicate shall be presented, for example, cursor changes back to normal shape.

56.2.3 Interrupt to End Keyboard Lockout—When keyboard lockout has occurred, the user shall be provided with a capability to abort a transaction that has resulted in an extended lockout. Such capability shall act like an UNDO command that stops ongoing processing and does not RESET the computer thereby losing prior processing.

56.3 Simplicity—Control/display relationships shall be straightforward and explicit. Control actions shall be simple and direct.

56.4 Accidental Actuation—Provision shall be made to prevent accidental actuation of potentially destructive control actions, including the possibility of accidental erasure or memory dump.

56.5 Compatibility with User Skill—Controls shall be compatible with the lowest anticipated user skill levels.

56.6 Availability of Information—Information necessary to select or enter a specific control action shall be available to the user when selection of that control action is appropriate.

56.7 Concurrent Display—Control actions to be selected from a discrete set of alternatives shall have those alternatives displayed before the time of selection. The current value of any
parameter or variable with which the user is interacting shall be displayed. User control inputs shall result in a positive feedback response displayed to indicate performance of requested actions.

56.8 Hierarchical Process—When hierarchical levels are used to control a process or sequence, the number of levels shall be minimized. Display and input formats shall be similar within levels and the system shall indicate the current positions within the sequence at all times.

56.9 User Memorization—The requirement to learn mnemonics, codes, special or long sequences, or special instructions shall be minimized.

56.10 Dialogue Type—The choice of dialogue type (for example, form filling, menus, command language) for interactive control shall be compatible with user characteristics and task requirements.

56.11 Number System—When numeric data is displayed or required for control input, such data shall be in the decimal, rather than binary, octal, hexadecimal, or other number system.

56.12 Data Manipulation—The user shall be able to manipulate data without concern for internal storage and retrieval mechanisms of the system.

56.13 Computer-Processing Constraints—The sequence of transaction selection shall generally be dictated by user choices and not by internal computer-processing constraints.

56.14 Feedback for Correct Input—Control feedback responses to correct user input shall consist of changes in state or value of those elements of the displays that are being controlled in an expected and logically natural form. An acknowledgement message shall be used only in those cases in which the more conventional mechanism is not appropriate or feedback response time must exceed 1 s.

56.15 Feedback for Erroneous Input—Where control input errors are detected by the system, error messages shall be available, and error recovery procedures shall be provided.

56.16 Control Input Data Display—The presence and location of control input data entered by the user shall be clearly and appropriately indicated. Data displayed shall not mislead the user with regard to nomenclature, units of measure, sequence of task steps, or time phasing.

56.17 Originator Identification—Except for broadcast communication systems, the transmitter of each message in inter-user communications shall be identified—automatically, if possible.

56.18 Menu Selection:

56.18.1 Use—Menu selection interactive control shall be used for tasks that involve little or no entry of arbitrary data and where users may have relatively little training. It shall also be used when a command set is so large that users are not likely to be able to commit all of the commands to memory.

56.18.2 Selection Devices—Lightpens or other pointing devices shall be used for menu selection. Where design constraints do not permit pointing devices, a standard window shall be provided for the user to key the selected option code.

56.18.3 Titles—Each page of options (menu) shall have a title that clarifies the purpose of that menu.

56.18.4 Series Entry—Users shall be provided the capability to stack menu selections, that is, to make several menu selections without having each menu displayed.

56.18.5 Sequences—A menu shall not consist of a long list of multipage options, but shall be logically segmented to allow several sequential selections among a few alternatives.

56.18.6 Active Option Presentation—The system shall present only menu selections for actions that are currently available.

56.18.7 Format Consistency—Menus shall be presented in a consistent format throughout the system and shall be readily available at all times.

56.18.8 Option Sequence—Menu selections shall be listed in a logical order, or, if no logical order exists, in the order of frequency of use.

56.18.9 Simple Menus—When the number of selections can fit on one page in two columns, a simple menu shall be used. If the selection options exceed two columns, hierarchical menus may be used.

56.18.10 Option Presentation—Selection codes and associated descriptors shall be presented on single lines.

56.18.11 Direct Function Call—If several levels of hierarchical menus are provided, a direct function call capability shall be provided such that the experienced user does not have to step through multiple menu levels.

56.18.12 Consistency With Command Language—When menu selection is used to train in the use of a command language, the wording and order shall be consistent with the command language.

56.18.13 Option Coding—When selections are indicated by coded entry, the code associated with each option shall be included on the display in some consistent manner.

56.18.14 Keyed Codes—If menu selections must be made by keyed codes, the options shall be coded by the first several letters of their displayed labels rather than by more arbitrary numeric codes.

56.18.15 Position in Structure—When menu traversal can be accomplished by clearly defined hierarchical paths, the user shall be given some indication of the displayed menu’s current position in the overall or relevant structure, such as by having an optional display of “path” information. A menu tree showing the menu hierarchy shall be included in the user manual.

56.18.16 Back Menu—When using hierarchical menus, the user shall be able to return to the next higher level by using single key action until the initial, top-level menu or display is reached.

56.18.17 Return to Top Level—A function shall be provided to directly recall the initial, top-level menu or display without stepping through the menu or display hierarchy.

56.19 Form Filling:

56.19.1 Use—Form-filling interactive control may be used when some flexibility in data to be entered is needed and where the users will have moderate training.

56.19.2 Grouping—Displayed forms shall be arranged such that related items are grouped together.

56.19.3 Format and Content Consistency—The format and content of displayed forms shall be perceptually related to that
of paper forms, if paper forms are used to guide data entry. A standard input form shall be used.

56.19.4 Distinctiveness of Fields—Fields or groups of fields shall be separated by lines or other delineation cues. Required fields shall be distinguished from optional fields.

56.19.5 Field Labels—Field labels shall be distinctively presented such that they can be distinguished from data entry. Labels for data entry fields shall incorporate additional cueing of data format where the entry is made up of multiple inputs, for example, DATE (M/D/Y): __/__/__.

56.19.6 Cursor—A displayed cursor shall be positioned by the system at the first data entry field when the form is displayed. The cursor shall be advanced by a tab key to the next data entry field when the user has completed entry of the current field.

56.19.7 Entry Length Indication—The maximum acceptable length for variable length fields shall be indicated.

56.19.8 Overwriting—Data entry by overwriting a set of characters in a field (such as a default) shall not be used.

56.19.9 Unused Underscores—When an item length is variable, the user shall not have to remove unused underscores.

56.19.10 Dimensional Units—When a consistent dimensional unit is used in a given entry field, the dimensional unit shall be provided by the computer. When the dimensional unit varies for a given field, it shall be provided, or selected, by the user.

56.19.11 User Omissions—When required data entries have not been input, the omission shall be indicated to the user and either immediate or delayed input of the missing items shall be allowed. For delayed entry, the user shall be required to enter a special symbol in the field to indicate that the missing item is delayed, not overlooked.

56.19.12 Nonentry Areas—Nonentry (protected) areas of the display shall be designated and made inaccessible to the user via the cursor.

56.19.13 Flexible Data Entry—When multiple data items are entered as a single transaction, the user shall be allowed to reenter, change, or cancel any item before taking a final ENTER action.

56.19.14 Information Labels—Descriptive wording shall be used when labeling data fields; use of arbitrary codes shall be avoided.

56.19.15 Logical Order—Where no source document or external information is involved, forms shall be designed so that data items are ordered in a logical sequence for input.

56.19.16 Form Filling for Control Entry—Form filling shall be considered as an aid for composing complex control entries. For example, for a print request, a displayed form might help the user invoke the various format controls that are available.

56.19.17 Fixed Function Keys—Fixed function key interactive control may be used for tasks requiring only a limited number of control inputs or in conjunction with other dialogue types.

56.20 Command Language:

56.20.1 Use—Command language interactive control may be used for tasks involving a wide range of user inputs and where user familiarity with the system can take advantage of the flexibility and speed of the control technique.

56.20.2 User Viewpoint—A command language shall reflect the user’s point of view such that the commands are logically related to the user’s conception of what is being done.

56.20.3 Distinctiveness—Commands shall be distinctive from one another.

56.20.4 Punctuation—The command language shall contain a minimum of punctuation or other special characters.

56.20.5 Abbreviations—The user shall be permitted to enter the full command name or an abbreviation for any command of more than five characters.

56.20.6 Standardization—All commands and their abbreviations, if any, shall be standardized and consistent with Section 28.

56.20.7 Displayed Location—Commands shall be entered and displayed in a standard location on the display.

56.20.8 Command Prompts—The user shall be able to request prompts, as necessary, to determine required parameters in a command entry.

56.20.9 Complexity—The command language shall be programmed in layers of complexity such that the basic layer will allow the inexperienced user to control a transaction. As this person’s skill increases, the command language shall allow skipping from basic to more advanced layers to meet the user’s current needs.

56.20.10 User Definition of Macro Commands—The programming shall not accept a user designated macro name that is the same as an existing command name.

56.20.11 Standard Techniques for Command Editing—Users shall be allowed to edit erroneous command entries with the same techniques that are used to edit data entries since consistent editing techniques will speed learning and reduce errors.

56.20.12 Destructive Commands—Where a command entry may have disruptive consequences, the user shall be required to review and confirm a displayed interpretation of the command before it is executed.

56.21 Questions and Answers:

56.21.1 Use—Question-and-answer dialogues shall be considered for routine data entry tasks in which data items are known and their ordering can be constrained, users will have little or no training, and the computer is expected to have medium response speed.

56.21.2 Questions Displayed Separately—Each question shall be displayed separately in question-and-answer dialogues; users shall not be required to answer several questions at once.

56.21.3 Recapitulating Prior Answers—When a series of computer-posed questions are interrelated, answers to previous questions shall be displayed when those will provide context to help a user answer the current questions.

56.21.4 Source Document Capability—When questions prompt entry of data from a source document, the question sequence shall match the data sequence in the source document.

56.22 Query Language:
56.22.1 **Use**—Query language dialogue shall be used for tasks emphasizing unpredictable information retrieval (as in many analysis and planning tasks), with moderately trained users.

56.22.2 **Natural Organization of Data**—Query languages shall reflect a data structure or organization perceived by users to be natural. For example, if a user supposes that all data about a particular topic are stored in one place, then the query language shall permit such data to be retrieved by a single query, even though actual computer storage might carry the various data in different files.

56.22.3 **Coherent Representation of Data Organization**—A single representation of the data organization for use in query formulation shall be established, for example, if different queries will access different databases over different routes, the user shall not necessarily need to know this.

56.22.4 **Task-Oriented Wording**—The wording of a query shall simply specify what data are requested; a user shall not have to tell the computer how to find the data.

56.22.5 **Logic to Link Queries**—The query language shall be designed to include logic elements that permit users to link (for example, “and,” “or”) sequential queries as a single entry.

56.22.6 **Confirming Large-Scale Retrieval**—If a query will result in a large-scale data retrieval, the user shall be required to confirm the transaction or else take further action to narrow the query before processing.

56.23 **Graphic Interaction:**

56.23.1 **Use**—Graphic interaction as a dialogue may be considered for use by casual users to provide graphic aids as a supplement to other types of interactive control.

56.23.2 **Iconic Menus**—When system users have different linguistic backgrounds, graphic menus may be used which display icons to represent the control options.

56.23.3 **Supplementary Verbal Labels**—Where icons are used to represent control actions in menus, verbal labels shall be displayed with each icon to help assure that its intended meaning will be understood.

56.24 **Feedback:**

56.24.1 **Use**—Feedback shall be provided which presents status information, confirmation, and verification throughout the interaction.

56.24.2 **Standby**—When system functioning requires the user to standby, WORKING, BUSY, or WAIT messages shall be displayed until user interaction is again possible. Where the delay is likely to exceed 15 s, the user shall be informed. For delays exceeding 60 s, a countdown display shall show delay time remaining. (See 56.27).

56.24.3 **Process Outcome**—When a control process or sequence is completed or aborted by the system, positive indication shall be presented to the user concerning the outcome of the process and the requirements for subsequent user action.

56.24.4 **Input Confirmation**—Confirmation shall not cause displayed data removal.

56.24.5 **Current Modes**—When multiple modes of operation exist, a means shall be provided to remind the user of the current mode.

56.24.6 **Highlighted Option Selected**—When a displayed message or datum is selected as an option or input to the system, the subject item shall be highlighted to indicate acknowledgment by the system.

56.24.7 **User Input Rejection**—If the system rejects a user input, feedback shall be provided to indicate the reason for rejection and the required corrective action. Feedback shall be self-explanatory.

56.24.8 **Feedback Message Content**—Users shall not be required to translate feedback messages by use of reference system or code sheets. Abbreviations shall not be used unless necessary.

56.24.9 **Time-Consuming Processes**—The system shall give warning information when a command is invoked which will be time-consuming or expensive to process.

56.25 **Prompts:**

56.25.1 **Use**—Prompts and help instructions shall be used to explain commands, error messages, system capabilities, display formats, procedures, and sequences and to provide data. Prompting shall conform to the following:

56.25.1.1 When operating in special modes, the system shall display the mode designation and file(s) being processed.

56.25.1.2 Before processing any user requests that would result in extensive or final changes to existing data, the system shall require user confirmation.

56.25.1.3 When missing data are detected, the system shall prompt the user.

56.25.1.4 When data entries or changes will be nullified by an abort action, the user shall be requested to confirm the abort.

56.25.1.5 Neither humor nor admonishment shall be used in structuring messages; the dialog shall be strictly factual and informative for the user.

56.25.1.6 Error messages shall appear as close as possible to the user entry that caused the message.

56.25.1.7 If a user repeats an entry error, the second error message shall be revised to include a noticeable change so that the user may be certain that the computer has processed the attempted correction.

56.25.2 **Standard Display**—Prompting messages shall be displayed in a standardized area of the displays.

56.25.3 **Explicit Prompts**—Prompts and help instructions for system-controlled dialogue shall be explicit, and the user shall not be required to memorize lengthy sequences or refer to secondary written procedural references.

56.25.4 **Prompt Clarity**—Prompts shall be clear and understandable. They shall not require reference to coding schemes or conventions which may be unfamiliar to occasional users.

56.25.5 **Definitions**—A dictionary of abbreviations and codes shall be available on-line. Definitions of allowable options and ranges of values shall be displayable at the user’s request.

56.25.6 **Consistent Terminology**—On-line documentation, off-line documentation, and help instructions shall use consistent terminology.

56.25.7 **User Confirmation**—User acceptance of stored data or defaults shall be possible by a single confirming keystroke.

56.26 **Default:**
56.26.1 **Workload Reduction**—Default values shall be used to reduce user workload. Currently defined default values shall be displayed automatically in their appropriate data fields with the initiation of a data entry transaction and the user shall indicate acceptance of the default.

56.26.2 **User Selection**—The user shall have the option of generating default values based on operational experience if the systems designer cannot predefine appropriate values.

56.26.3 **Default Substitution**—The user shall be able to replace any default value during a given transaction without changing the default definition.

56.26.4 **Defaults for Sequential Entries**—Where a series of default values have been defined for a data entry sequence, the user shall be allowed to default all entries or to default until the next required entry. The experienced user may not wish to accept each default value for each data field individually.

56.27 **Error Management/Data Protection**:

56.27.1 **Error Correction**—Where users are required to make entries into a system, an easy means shall be provided for correcting erroneous entries. The system shall permit correction of individual errors without requiring reentry of correctly entered commands or data elements.

56.27.2 **Early Detection**—A capability shall be provided to facilitate detection and correction of errors after keying in but before entering into the system. While it is desirable that errors be detected early, error checking shall occur at logical data entry breaks, for example, at the end of data fields rather than character by character to avoid disrupting the user.

56.27.3 **Internal Software Checks**—User errors shall be minimized by use of internal software checks of user entries for validity of item, sequence of entry, completeness of entry, and range of value.

56.27.4 **Critical Entries**—The system shall require the user to acknowledge critical entries before their being implemented by the system. An explicitly labeled CONFIRM function key, different from the ENTER key, shall be provided for user confirmation of control and data entries that have been questioned by the computer.

56.27.5 **Error Message Content**—Error message shall be constructive and neutral in tone, avoiding phrases that suggest a judgment of the user’s behavior. The error messages shall reflect the user’s view, not that of the programmer. Error messages shall be appropriate to the user’s level of training, be as specific as possible to the user’s particular application, and describe a way to remedy, recover, or escape from the error situation.

56.27.6 **Error Recovery and Process Change**—The user shall be able to stop the control process at any point in a sequence as a result of indicated error or as an option. The user shall be able to return easily to previous levels in multistep processes to nullify an error or to effect a desired change.

56.27.7 **Diagnostic Information**—Error messages shall explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition. Where clear inference is not possible, probable helpful inference(s) may be offered.

56.27.8 **Correction Entry and Confirmation**—When the user enters correction of an error, such corrections shall be implemented by an explicit action by the user (for example, actuation of an ENTER key.) All error corrections by the user shall be acknowledged by the systems either by indicating a correct entry has been made or by another error message.

56.27.9 **Spelling Errors**—Spelling and other common errors shall not produce valid system commands or initiate transactions different from those intended. When possible, the system shall recognize common misspellings of commands and execute the commands as if spelling had been correct. Computer-corrected commands, values, and spellings shall be displayed and highlighted for user confirmation.

56.27.10 **Errors in Stacked Commands**—To prompt for corrections of an error in stacked commands, the system shall display the stacked sequence with the error highlighted. Where possible, a procedure shall be provided to correct the error and salvage the stack.

56.27.11 **Display of Errorneous Entries**—A computer-detected error, as well as the error message, shall be continuously displayed until the error is corrected.

56.27.12 **Help**—In addition to explicit error management aids, (labels, prompts, advisory messages) and implicit aids (cuing), users shall be able to obtain further on-line guidance by requesting HELP. Following the output of a simple error message, users shall be permitted to request a more detailed discussion at levels of increasing detail.

56.27.12.1 **Standard Action to Request HELP**—A simple, standard action that is always available shall be provided to request HELP.

56.27.12.2 **Multilevel HELP**—When an initial HELP display provides only summary information, more detailed explanations shall be provided in response to repeated user requests for HELP.

56.27.12.3 **Browsing HELP**—Users shall be permitted to browse through on-line HELP displays, just as they would through a printed manual, to gain familiarity with system functions and operating procedures.

56.27.13 **Data Security**—Data shall be protected from unauthorized use, potential loss from equipment failure, and user errors.

56.27.13.1 **Automated Security Measures**—Automated measures shall be provided to minimize data loss from intruders in a system or from errors by legitimate users.

56.27.13.2 **Warning of Threats to Security**—Computer logic shall be provided that will generate messages or alarm signals or both to warn users of attempted intrusion by unauthorized users.

56.27.13.3 **Segregating Real from Simulated Data**—When simulated data and system functions are provided (perhaps for user training), real data shall be protected and real system use shall be clearly distinguished from all simulated operations.

56.27.13.4 **Display of Simulated Data**—In applications in which either real or simulated data can be displayed, a clear indication of simulated data shall be included as part of the classification label.

56.27.13.5 **Displayed Security Classification**—When displayed data are classified for security purposes, a prominent indication of security classification level shall be labeled in each display.
56.27.13.6 User Identification—User identification procedures shall be as simple as possible, consistent with adequate data protection. For protection of the password, the password shall not be echoed on the display. Audio feedback, rather than visual, shall be provided when imputing secure passwords during log on.

56.27.13.7 Choice of Passwords—When passwords are required, users shall be allowed to choose their own passwords since a password chosen by a user will generally be easier for that individual to remember. Guidelines for password selection shall be given so that users will not choose easily guessable ones.

56.27.13.8 Changing Passwords—Users shall be allowed to change passwords whenever they choose; all passwords shall be changed at periodic intervals.

56.28 System Response Time—Maximum system response times for real-time systems (for example, fire-control systems, command and control systems) shall not exceed the values of Table 51. Non-real-time systems may permit relaxed response times. If computer response time will exceed 15 s, the user shall be given a message indicating that the system is responding.

56.29 Other Requirements:

56.29.1 Overlays—Mechanical overlays, such as coverings over the keyboard or transparent sheet placed on the display, shall be avoided.

<table>
<thead>
<tr>
<th>System Interpretation</th>
<th>Response Time Definition</th>
<th>Maximum Acceptable Response Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key response</td>
<td>Key depression until positive response; for example “click”</td>
<td>0.1</td>
</tr>
<tr>
<td>Key print</td>
<td>Key depression until appearance of character</td>
<td>0.2</td>
</tr>
<tr>
<td>Page turn</td>
<td>End of request until first few lines are visible</td>
<td>1.0</td>
</tr>
<tr>
<td>Page scan</td>
<td>End of request until text begins to scroll</td>
<td>0.5</td>
</tr>
<tr>
<td>XY entry</td>
<td>From selection of field until visual verification</td>
<td>0.2</td>
</tr>
<tr>
<td>Function</td>
<td>From selection of command until response</td>
<td>2.0</td>
</tr>
<tr>
<td>Pointing</td>
<td>From input of point to display point</td>
<td>0.2</td>
</tr>
<tr>
<td>Sketching</td>
<td>From input of point to display of line</td>
<td>0.2</td>
</tr>
<tr>
<td>Local update</td>
<td>Change to image using local database; for example, new menu list from display buffer</td>
<td>0.5</td>
</tr>
<tr>
<td>Host update</td>
<td>Change where data is at host in readily accessible form; for example, a scale change of existing image</td>
<td>2.0</td>
</tr>
<tr>
<td>File update</td>
<td>Image update requires an access to a host file</td>
<td>10.0</td>
</tr>
<tr>
<td>Inquiry (simple)</td>
<td>From command until display of a commonly used message</td>
<td>2.0</td>
</tr>
<tr>
<td>Inquiry (complex)</td>
<td>Response message requires domain-used calculations in graphic form</td>
<td>10.0</td>
</tr>
<tr>
<td>Error feedback</td>
<td>From entry of input until error message appears</td>
<td>2.0</td>
</tr>
</tbody>
</table>

56.29.2 Hard Copy—The user shall have the capability to obtain a paper copy of the exact contents of the alphanumeric or digital graphic display in those systems where:

56.29.2.1 Mass storage is restricted.
56.29.2.2 Mass stored data can be lost by power interruption or
56.29.2.3 Record keeping is required.

56.29.3 Display Print—The user shall be able to print a display by simple request (for example, PRINT-SCREEN) without having to take a series of other actions first, such as calling for the display to be filed, specifying a filename, then calling for a print of that named file.

56.29.4 Print Page—The user shall have the capability to request printing of a single page, or sequence of pages, by specifying the page numbers.

56.29.5 Functional Integration—Data transmission functions shall be integrated with other information-handling functions within a system. A user shall be able to transmit data using the same computer system and procedures used for general entry, display, and other processing of data.

56.29.6 Consistent Procedures—Procedures for preparing, sending, and receiving data and messages shall be consistent from one transaction to another and consistent with procedures for other information-handling tasks.

56.29.7 Minimal Memory Load on Users—The data transmission procedures shall minimize memory load on the users by providing computer aids for automatic insertion of standard information, such as headers and distribution lists.

56.29.8 Interrupt—Users shall be allowed to interrupt message preparation, review, or disposition and then resume any of those tasks from the point of interruption.

56.29.9 Stored Message Forms—Where formats conform to a defined standard or are predictable in other ways, prestored forms shall be provided to aid users in message preparation.

56.29.10 Incorporate Existing Files—Users shall be allowed to incorporate an existing data file in a message or to combine several files into a single message for transmission and to combine stored data with new data when preparing messages for transmission. It shall not be necessary to reenter any data already entered for other purposes.

56.29.11 Addresses:

56.29.11.1 Prompting Address Entry—When users must specify the address for messages, prompting shall be provided to guide the user in the process.

56.29.11.2 Address Directory—Users shall be provided with an on-line directory showing all acceptable forms of message addressing for each destination in the system and for links to external systems.

56.29.11.3 Aids for Director Search—Computer aids shall be provided so that a user can search an address directory by specifying a complete or partial name. It shall also be possible to extract selected addresses from a directory for direct insertion into a header to specify the destination(s) for a message.

56.30 Software:

56.30.1 General—The design of computer program shall provide adequate information and respond within required time
limits with sufficient detail and precision to ensure mission accomplishment while minimizing physical and mental stress on the users.

56.30.2 Information and System Response—The information displayed to the user, such as symbols, display codes, prompts, alerts, and alarms shall be limited to that which is necessary to perform specific actions or to make decisions.

56.30.3 Computer Failure—In the event of computer failure, the program shall allow for orderly shutdown and establishment of a checkpoint so restoration can be accomplished without loss of computing performed to date.

56.30.4 Task Complexity—Software shall minimize user task complexity. Control inputs shall be simplified to the extent possible, particularly for tasks requiring real-time responses, and shall permit logical task sequences with a minimum number of control manipulations to achieve task completion.

56.30.5 Interaction—Where two or more users must have simultaneous read access to the computer program or data-processing results from multiple personnel-equipment interfaces, the operation by one person shall not interfere with the operations of another person unless mission survival may be contingent upon the preemption. Provisions shall be made so that the preempted user can resume operations at the point of interference without information loss.
Standard Specification for
Fuel Oil Meters of the Volumetric Positive Displacement Type

This standard is issued under the fixed designation F 1172; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides the minimum requirements for the design, fabrication, pressure rating, marking, and testing for fuel oil meters (volumetric positive displacement type).

1.2 The values stated in inch-pound units are to be regarded as the standard. Metric (SI) units are provided for information only.

1.3 The following safety hazards caveat pertains only to the test method section of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
F 722 Specification for Welded Joints for Shipboard Piping Systems

2.2 ANSI Standards:
B2.1 Pipe Threads
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable-Iron Screwed Fittings
B16.4 Cast-Iron Screwed Fittings
B16.5 Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings Socket-Welding and Threaded
B16.34 Valves, Flanged and Buttwelding End
B31.1 Power Piping

2.3 Manufacturers’ Standardization Society of the Valve and Fittings Industry.
MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.4 API Standard:
Code No. 1101 Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter

2.5 American Society of Mechanical Engineers:
ASME Boiler and Pressure Vessel Code, Section VIII, Div. I, Pressure Vessels; Section IX, Welding and Brazing Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 fuel oil meter (volumetric positive displacement type)—device intended to indicate the volume of liquid fuel oil delivered to a fuel distribution system over a period of time.
3.1.2 maximum allowable working pressure (MAWP)—maximum system pressure to which a fuel oil meter may be subjected.

4. Ordering Information

4.1 Orders for products under this specification shall include the following applicable information:
4.1.1 Title, number, and date of this specification.
4.1.2 Operating pressure (psi) and temperature (°F).
4.1.3 End connection and size.
4.1.4 Maximum capacity required.
4.1.5 Type of fuel service.
4.1.6 Materials—external and internal.
4.1.7 Other test requirements.
4.1.8 Qualification test reports as required.

5. Materials and Manufacture

5.1 Fuel oil meter casings, as well as any pressure-retaining parts, shall be constructed of ferrous material as listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. All other parts shall be constructed of materials suitable for the service intended. Fasteners in contact with interior fluid shall be of corrosion-resistant steel.

5.2 Seals and associated parts shall be of materials suitable for the service and the fluid to be measured.

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.
4 Available from Manufacturer’s Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.

5 Available from American Petroleum Institute, 1801 K St., N.W., Washington, DC 20226.
6 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.
5.3 Manufacture:
5.3.1 Fuel oil meters with end fittings in compliance with ANSI Standards B2.1, B16.1, B16.3, B16.4, B16.5, B16.11, or B16.34 as appropriate may be used within the pressure-temperature ranges permitted by the applicable standard provided the meter housing is satisfactory for these conditions.
5.3.2 Threaded fittings above two nominal pipe size (NPS) and socket welded flanges above 3 NPS shall not be used in fuel oil meters with a MAWP above 150 psig (1 N/mm²) and for service above 150°F (65°C).
5.4 Welding procedure qualification, welder performance qualification, and welding materials shall be in accordance with ANSI B31.1 and Section IX of the ASME Code. Brazing or soldering shall not be used.

6. Other Requirements
6.1 Components:
6.1.1 The meter shall consist of a housing with measuring mechanism and a register with counter mechanism.
6.1.1.1 Measuring Chamber—The measuring chamber for all meters shall be so constructed as not to show distortion under maximum allowable working pressure in any manner, or to affect the sensitivity of the meter.
6.1.1.2 Adjusting Device—The meter shall be provided with an adjusting device for changing the registered quantity to attain desired calibration. The adjustment setting shall have provisions for locking and shall not change during the meter life except by manual readjustment. The adjusting device shall be noncyclical and shall permit adjustment without disassembly of the mechanism except for removal of adjusting device cover plate. The plate shall be sealed by means of a lead seal. The meter shall be capable of calibration adjustment over a minimum range of 5 %.
6.1.1.3 Direction Marking of Meter—Directions for positive and negative adjustment shall be permanently marked on the meter.
6.1.1.4 Register—The register shall be of the direct-reading type. The register shall have a nonsetback total indicator and a setback-type run indicator, so that individual runs can be registered without affecting the total of all runs, as shown on the total indicator. The total indicator shall have a minimum of eight figures, and the setback run indicator shall have a minimum of five figures. Reset digits shall have a minimum height of ½ in. (13 mm) and shall not be coated with fluorescent paint. The indicating register shall read in U.S. gallons of 231 in.³ (3.785 41 × 10⁻³ m³) each. The register shall be isolated from the fluid.
6.1.1.5 Register Face—The register shall have a transparent, colorless plastic face of such size that all digits shall be easily read. Glass shall not be used.
6.2 Rating, Design, and Fabrication:
6.2.1 The maximum allowable working pressure-temperature rating (MAWP) for fuel oil meters conforming to this standard shall be established by at least one of the following methods:
6.2.1.1 Proof test in accordance with the requirements prescribed in Paragraph UG-101 of Section VIII of the ASME Code. If burst-type tests as outlined in Paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of B to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture. Components that have been subjected to a hydrostatic proof test shall not be offered for sale.
6.2.1.2 The water temperature shall not exceed 125°F (52°C) during the test.
6.2.2 Design calculations are in accordance with the requirements prescribed in Section VIII, Division I of the ASME Code.
6.3 Where welded construction is used for the fabrication of pressure containing parts, welded joint design details shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F 722. Except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.
6.4 Inlet and outlet connections consisting of welded flanges and fittings shall be in accordance with Specification F 722. When radiography is required (see 10.2), all welds shall be butt welds for Class I piping as required by Specification F 722, except packing cylinders, drains, and similar ancillary connections may be attached by fillet or socket welds.
6.5 Capacity—The maximum capacity of the meter shall be as specified by the manufacturer.
6.6 Pressure Drop—The maximum pressure drop between the meter inlet and outlet shall not exceed 5 psi (34 MPa) as certified by testing in accordance with 8.1.1.2.
6.7 Error, Normal Flow—For flow rate and calibration setting between 5 and 100 % of maximum capacity, the error of the meter shall not exceed 0.1 % for any one predetermined flow rate and accuracy setting.
6.8 Maintainability—The meter shall be so designed as not to require special tools for overhaul and repair.

7. Workmanship, Finish, and Appearance
7.1 Meter shall have all burrs or sharp edges removed and shall be cleaned of all loose metal chips and other foreign substances.
7.2 Treatment and Painting—The exterior surface of the meter shall be treated and painted in accordance with best commercial practice.

8. Number of Tests
8.1 Qualification Tests:
8.1.1 A representative fuel oil meter of each particular design shall be certified as having undergone the following qualification tests.
8.1.1.1 Calibration and adjustment:
The meter shall be tested in accordance with applicable sections of API Code 1101.
8.1.1.2 Pressure drop—Clean fluid at 35 Saybolt seconds Universal (SSU) shall be pumped through the meter at 100 % of manufacturer’s rated capacity. After the flow rate has been stabilized, the measured pressure drop between the inlet and outlet of the meter shall not exceed 5 psi (34 MPa).
8.2 Production Tests:
8.2.1 The manufacturer shall production test each fuel oil meter by hydrostatic test methods as described in Section 9.
8.2.2 Each meter shall be calibration tested at mid range of flow capacity. The reading error shall not exceed 0.1 % at this flow rate.

9. Test Methods

9.1 Hydrostatic Test—Each fuel oil meter shall be given a hydrostatic shell test of at least 1½ times its maximum allowable working pressure.

9.1.1 The fluid temperature shall not exceed 125°F (52°C) during the hydrostatic test, and the fluid used should be nonflammable. Further, it should not cause rusting and should otherwise be compatible with the internal parts of the fuel oil meter.

9.1.2 The test arrangement shall be air free before pressurization.

9.1.3 The minimum duration of the shell test shall be 30 s at required pressure.

9.1.4 No visible leakage or structural damage shall show during the test.

10. Inspection

10.1 Each finished fuel oil meter shall be visually examined and dimensionally checked to ensure that the meter corresponds to this specification and is marked in accordance with Section 12.

10.2 Nondestructive Examination of Welds:
10.2.1 All welds shall be visually examined in accordance with ANSI B31.1.

10.2.2 Welded inlet and outlet connections that are equal to or greater than 4 NPS or greater than 0.375-in. nominal wall thickness which are in services greater than 150 psig (1 N/mm²) and 150°F (65°C) shall be 100 % radiographically examined.

11. Certification

11.1 The pressure ratings established under this specification are based upon materials of high quality produced under regular control of chemical and physical properties by a recognized process. The manufacturer shall be prepared to certify that his product has been so produced and that the physical and chemical properties thereof, as proven by test specimens and nondestructive testing or as documented by certifications from the producer or recognized distributor of these materials, are at least equal to the requirements of the appropriate specifications.

11.2 When specified in the purchase order or contract, the manufacturer certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

11.3 Certification of the MAWP shall be available to purchasers.

12. Product Marking

12.1 Each fuel oil meter shall be permanently marked with the following:

12.1.1 Manufacturer’s name or trademark.

12.1.2 Maximum allowable working pressure—temperature rating (MAWP).

12.1.3 Flow Direction—The direction of flow through the meter shall be indicated by the words “inlet” and “outlet,” a directional arrow, or both, stamped or embossed on the meter.

12.1.4 End fittings complying with a standard listed in 5.3.1 may be marked in accordance with the applicable requirements of MSS SP-25 for dimensional identification purposes if desired.

12.1.5 Size (end connection size), may be included at the option of the manufacturer.

12.1.6 ASTM designation of this specification.


13.1 The manufacturer of the fuel oil meter shall maintain the quality of the meters that are designed, tested, and marked in accordance with this specification. At no time shall a meter be sold that is marked with this standard designation that does not meet the requirements herein.

14. Keywords

14.1 fuel oil; fuel oil meters; meters; volumetric positive displacement meters
Standard Specification for Thermosetting Resin Fiberglass Pipe Systems to Be Used for Marine Applications

This standard is issued under the fixed designation F 1173; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers reinforced thermosetting resin pipe systems with nominal pipe sizes (NPS) 1 through 48 in. (25 through 1200 mm) which are to be used for all fluids approved by the authority having jurisdiction in marine piping systems.

1.2 Values stated in inch-pound are to be regarded as the standard. Values given in parentheses are for information only.

1.3 The dimensionless designator NPS has been substituted for traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.4 The following safety hazards caveat pertains to the test methods which are included in this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D 883 Terminology Relating to Plastics
D 1598 Test Method for Time-To-Failure of Plastic Pipe Under Constant Internal Pressure
D 1599 Test Method for Resistance to Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings
D 2105 Test Method for Longitudinal Tensile Properties of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
D 2310 Classification for Machine-Made “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D 2584 Test Method for Ignition Loss of Cured Reinforced Resins
D 2924 Test Method for External Pressure Resistance of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D 3567 Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D 5028 Test Method for Curing Properties of Pultrusion Resins by Thermal Analysis
D 5686 Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Pipe Fittings, Adhesive Bonded Joint Type Epoxy Resin, for Condensate Return Lines
E 1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies
F 412 Terminology Relating to Plastic Piping Systems

2.2 Other Documents:
ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings
ANSI B16.5 Pipe Flanges and Flanged Fittings
IMO Resolution A.753(18) Guidelines for the Application of Plastic Pipes on Ships
IMO Resolution A.653(16) Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials
NSF-61
Code of Federal Regulations Title 46, Part 56, for Piping Systems, and Subpart 56.60-25 for Nonmetallic Materials
IMO Resolution A.653(16) Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials

2 Annual Book of ASTM Standards, Vol 08.01.
4 Annual Book of ASTM Standards, Vol 08.02.
5 Annual Book of ASTM Standards, Vol 08.03.
7 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.
8 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.
9 Available from the National Sanitation Foundation, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140.
IMO Resolution MSC.61(67) International Code for Application of Fire Test Procedures
OTI 95 634 Jet-Fire Resistance Test of Passive Fire Protection Materials

2.3 ISO Documents:
9001
7
75

3. Terminology
3.1 Definitions are in accordance with Terminologies D 883 and F 412.
3.2 Definitions of Terms Specific to This Standard:
3.2.1 continuously electrically conductive, adv—pipe and fittings made conductive using discretely conductive materials or layers.
3.2.2 homogeneously electrically conductive, adv—pipe and fittings made conductive using a resin additive so that conductivity is maintained between any two points on the pipe or fitting.
3.2.2.1 Discussion—For conveying nonconducting fluids (those having conductance less than 1000 pico-Siemens per metre), pipe systems which are continuously or homogeneously conductive or have conductivity from the inside surface to the outside surface are recommended. In accordance with IMO Resolution A.753(18), all pipe located in a hazard—ous area, regardless of the fluid being conveyed, must be electrically conductive.
3.2.3 maximum operating pressure, n—the highest pressure that can exist in a system or subsystem under normal operating conditions.
3.2.4 representative piping system, n—a system composed of a single manufacturer’s pipes, fittings, joints, and adhesives that would normally be used by a customer or installer.

4. Classification
4.1 General—Pipe and fittings are to be classified using the following system which is similar to that of Classification D 2310 for pipe.
4.1.1 Types:
4.1.1.1 Type I—Filament wound.
4.1.1.2 Type II—Centrifugally cast.
4.1.1.3 Type III—Molded (fittings only).
4.1.2 Resin:
4.1.2.1 Resin 1—Epoxy resin.
4.1.2.2 Resin 2—Vinylester resin.
4.1.2.3 Resin 3—Polyester resin.
4.1.2.4 Resin 4—Phenolic resin.
4.1.2.5 Resin 5—Customer-specified resin.
4.1.3 Class:
4.1.3.1 Class A—No liner.
4.1.3.2 Class B—Reinforced liner.
4.1.3.3 Class C—Nonreinforced liner.
4.2 Pressure Rating—Pipe and fittings shall be classified as to the method used to obtain their pressure rating (refer to Appendix X1).

4.2.1 Rating Method 1—Short-term test.
4.2.2 Rating Method 2—Medium-term (1000-h) test.
4.2.3 Rating Method 3—Long-term (10 000-h) test.
4.2.4 Rating Method 4—Long-term (10 000-h) regression test.

4.3 Fire Endurance—Piping systems are to be classified in accordance with the following cells if fire performance is to be specified (refer to Appendix X2).
4.3.1 Fluid:
4.3.1.1 Fluid E—Empty.
4.3.1.2 Fluid EF—Initially empty for 5 min, followed by flowing water. Fluid velocity of 3-ft/s maximum during qualification test.)
4.3.1.3 Fluid S—Stagnant water.
4.3.2 Fire Type:
4.3.2.1 Fire Type JF—Jet fire with heat flux between 95 100 and 126 800 Btu/(h-ft²) (300 and 400 kW/m²).
4.3.2.2 Fire Type IF—Impinging flame with heat flux of 36 011 Btu/(h-ft²) (113.6 kW/m²).
4.3.2.3 Fire Type HF—Hydrocarbon furnace test at 1102°F (1110°C).

4.3.3 Integrity/Duration:
4.3.3.1 Integrity A—No leakage during or after fire test.
4.3.3.2 Integrity B—No leakage during fire test, except a slight weeping is acceptable. Capable of maintaining rated pressure for a minimum of 15 min with a leakage rate of 0.05 gal/min (0.2 L/min) after cooling.
4.3.3.3 Integrity C—Minimal or no leakage (0.13 gal/min (0.5 L/min)) during fire test. Capable of maintaining rated pressure with a customer-specified leakage rate after cooling.
4.3.3.4 Duration—The duration of the test shall be specified in minutes and shall be specified or approved by the authority having jurisdiction.

5. Ordering Information
5.1 When ordering pipe and fittings under this specification, the following should be specified (where applicable):
5.1.1 Service Conditions:
5.1.1.1 Fluid being transported.
5.1.1.2 Design temperature (reference 6.6).
5.1.1.3 Internal design pressure.
5.1.1.4 External design pressure.
5.1.2 General Information:
5.1.2.1 Type (reference 4.1.1).
5.1.2.2 Resin (reference 4.1.2).
5.1.2.3 Class (reference 4.1.3).
5.1.3 Pressure Rating Method (Internal Only) (reference 4.2).
5.1.4 Fire Endurance:
5.1.4.1 Fluid (reference 4.3.1).
5.1.4.2 Fire type (reference 4.3.2).
5.1.4.3 Integrity (reference 4.3.3).
5.1.4.4 Flame spread rating (reference 6.4).
5.1.4.5 Smoke and other toxic products of combustion (reference 6.5).
5.1.5 NPS.
5.1.6 Manufacturer’s Identification (part number, product name, and so forth).
5.1.7 Specific job requirements (that is, potable water usage, electrical conductivity).

6. Performance Requirements

6.1 Internal Pressure—All components included in the piping system shall have pressure ratings suitable for the intended service. Pressure ratings shall be determined in accordance with Appendix X1 using the method specified by the customer or a longer-term method, if available. If, for example, a Rating Method 2—medium-term test is specified and data for Rating Method 3—long-term test is available, then the long-term test data is acceptable. Note that for some components, particularly specialty fittings, long-term testing is not practical and ratings for these items will typically be determined using Rating Test Method 1.

6.2 External Pressure—All pipe included in the piping system shall have external pressure ratings suitable for the intended service. External pressure ratings shall be determined by dividing the results of Test Method D 2924 by a minimum safety factor of 3.

6.3 Fire Endurance—The piping system shall have the fire endurance required by the authority having jurisdiction based on the intended location and service. Fire endurance shall be determined using the appropriate method in Appendix X2.

6.4 Flame Spread—The authority having jurisdiction shall designate any flame spread requirements based on the location of the piping. For ships, mobile offshore drilling units (MODU’s), and floating oil production platforms subject to the requirements of SOLAS or Title 46 of the U.S. Code of Federal Regulations, performance shall be determined by test procedures given in IMO Resolution MSC.61(67), Annex 1, Part 5—Test for Surface Flammability, as modified for pipes in Appendix 3 of IMO Resolution A.753(18).

6.5 Smoke and Other Toxic Products of Combustion—The authority having jurisdiction shall designate any smoke and toxicity requirements based on the location of the piping. For ships, MODUs, and floating oil production platforms subject to the requirements of SOLAS or Title 46 of the U.S. Code of Federal Regulations, performance shall be determined by test procedures given in IMO Resolution MSC.61(67), Annex 1, Part 2—Smoke and Toxicity Test, as modified in B.9.0 of Appendix B—Fire Performance Tests.

6.6 Temperature—The maximum working temperature shall be at least 36°F (20°C) less than the minimum glass transition temperature (determined in accordance with Test Method D 5028 or equivalent) or heat distortion temperature (determined in accordance with ISO 75 Method A, or equivalent) of the resin or plastic material. The minimum glass transition temperature or heat distortion temperature, whichever is less, shall not be less than 176°F (80°C).

Note 1—Glass transition temperature shall be used for in-process quality control testing (reference 9.1.4, 9.2.4, and 9.3.3).

6.7 Material Compatibility—The piping material shall be chemically compatible with the fluid being carried and any fluid in which it will be immersed.

6.8 Electrical Resistance—Conductive piping systems shall have a resistance per unit length not to exceed $3.05 \times 10^3 \Omega/ft$ ($1 \times 10^3 \Omega/m$) when tested in accordance with Appendix X3. Resistance to earth at any location on an installed piping system required to be conductive shall be no greater than $1 \times 10^6 \Omega$.

6.9 Static Charge Shielding—Conductive piping systems shall have a maximum resulting voltage not to exceed 1% of the supply voltage induced on the exterior surface of the pipe when tested in accordance with Appendix X3.

6.10 Potable Water Usage—The material, including pipe, fittings, adhesive, and any elastomeric gaskets required shall have no adverse effect on the health of personnel when used for potable water service. Material shall conform to National Sanitation Standard 61 or meet the requirements of FDA Regulations 21 CFR 175.105 and 21 CFR 177.2280, 21 CFR 177.2410, or 21 CFR 177.2420.

7. Other Requirements

7.1 Flanges—Standard flanges shall have bolt patterns in accordance with ANSI B16.5 Class 150 for nominal pipe sizes 24-in. and smaller and in accordance with ANSI B16.1 Class 125 for larger flanges. Consult the manufacturer’s literature for bolt length, torque specifications, and tightening sequence.

7.2 Military Usage—Piping and fittings used in military applications shall comply with the provisions of Appendix D, Supplementary Requirements to Specification F 1173 for U.S. Navy use.

8. Workmanship and Appearance

8.1 All pipe, fittings, and spools shall be visually inspected for compliance with the requirements stated in Table 1, and, if appropriate, either repaired or rejected. After all minor repairs, a pressure test in accordance with 9.1.1, 9.2.1, or 9.3.1 shall be performed on the component.

9. Inspection and Sampling

9.1 Pipe:

9.1.1 Pressure Tests—A minimum of 5% of pipe joints shall be tested at a pressure of not less than 1.5 times the pipe system pressure rating.

9.1.2 Lot Size—A lot of pipe shall consist of 150 joints, or fractions thereof, of one size, wall thickness, and grade in continuous production.

9.1.3 Short-Term Burst Tests—Short-term hydrostatic burst tests shall be conducted in accordance with Test Method D 1599 at a minimum frequency of one test per lot. If the measured value is less than 85% of the published value, the lot is rejected or subject to retest.

9.1.4 Degree of Cure—The glass transition temperature ($T_g$) shall be determined at a minimum frequency of one test per production lot. If the measured value is more than 10°F less than the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.1.5 Glass Content—The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with Test Method D 2584. If the measured glass content is not within 5% of the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.1.6 Wall Thickness—Total wall thickness and reinforced wall thickness shall be determined in accordance with Practice
TABLE 1 Visual Acceptance Criteria

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Description</th>
<th>Acceptance Criteria</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn</td>
<td>thermal decomposition indicated by distortion or discoloration of the laminate surface</td>
<td>none permitted</td>
<td>reject</td>
</tr>
<tr>
<td>Chip</td>
<td>small piece broken from edge or surface—if reinforcement fibers are broken, the damage is considered a crack</td>
<td>if there are undamaged fibers exposed over any area; or no fibers are exposed but an area greater than 0.4 in. (10 by 10 mm) lacks resin</td>
<td>minor repair</td>
</tr>
<tr>
<td></td>
<td>if no fibers are exposed, and the area lacking resin is less than 0.4 by 0.4 in. (10 by 10 mm)</td>
<td></td>
<td>accept</td>
</tr>
<tr>
<td>Crack</td>
<td>actual separation of the laminate which is visible on opposite surfaces and often extends through the wall; reinforcement fibers are often visible/broken</td>
<td>none permitted</td>
<td>reject</td>
</tr>
<tr>
<td>Crazing</td>
<td>fine hairline cracks at or under the surface of the laminate; white areas are not visible</td>
<td>crack lengths greater than 1.0 in (25.4 mm)</td>
<td>minor repair</td>
</tr>
<tr>
<td>Dry spot</td>
<td>area of incomplete surface film where the reinforcement has not been wetted by resin</td>
<td>crack lengths less than 1.0 in (25.4 mm)</td>
<td>accept</td>
</tr>
<tr>
<td>Fracture</td>
<td>rupture of the laminate with complete penetration; majority of fibers are broken; visible as lighter colored area of interlaminar separation</td>
<td>none permitted</td>
<td>reject</td>
</tr>
<tr>
<td>Inclusion</td>
<td>foreign matter wound into the laminate</td>
<td>none permitted in structural wall (treat same as pit if located at the surface)</td>
<td>reject</td>
</tr>
<tr>
<td>Pit (pinhole)</td>
<td>small crater in the surface of the laminate; width is on the same order of magnitude as the depth</td>
<td>diameter greater than 0.032 in. (0.8 mm) or depth greater than 10% of wall thickness, or both</td>
<td>minor repair</td>
</tr>
<tr>
<td></td>
<td>or diameter less than 0.032 in. (0.8 mm) and depth less than 10% of wall thickness</td>
<td></td>
<td>accept</td>
</tr>
<tr>
<td>Restriction</td>
<td>excessive resin, adhesive, or foreign matter on the internal wall of pipe/fittings</td>
<td>none permitted</td>
<td>remove by careful grinding</td>
</tr>
<tr>
<td>Wear scratch</td>
<td>shallow mark caused by improper handling, storage, or transportation, or combination thereof—if reinforcement fibers are broken, the damage is considered to be a crack</td>
<td>undamaged fibers exposed over any area or no fibers are exposed but an area greater than 0.4 by 0.4 in (10 by 10 mm) lacks resin</td>
<td>minor repair</td>
</tr>
<tr>
<td></td>
<td>if no fibers are exposed, and the area lacking resin is less than 0.4 by 0.4 in. (10 by 10 mm)</td>
<td></td>
<td>accept</td>
</tr>
</tbody>
</table>

TABLE 2 Wall Thickness Tolerances

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total wall thickness</td>
<td>+22.5 A</td>
</tr>
<tr>
<td></td>
<td>−0</td>
</tr>
<tr>
<td>Reinforced wall thickness</td>
<td>+22.5 A</td>
</tr>
<tr>
<td></td>
<td>−0</td>
</tr>
</tbody>
</table>

The tolerance on total and reinforced wall thickness for fittings shall refer to the manufacturer’s designated location on the body of the fitting.

9.2.4 Degree of Cure—The Tg shall be determined at a minimum frequency of one test per production lot. If the measured value is more than 10°F less than the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.2.5 Glass Content—The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with Test Method D 2584. If the measured glass content is not within 5% of the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.2.6 Wall Thickness—Total wall thickness and reinforced wall thickness shall be determined in accordance with Practice D 3567 once per every production lot. Total and reinforced wall thickness shall be as specified in Table 2. Any out of tolerance components shall be rejected.

9.3 Flanges and Mitered Fittings:

9.3.1 Pressure Tests—One mitered fitting from each lot shall be tested to a pressure equal to or greater than 1.5 times the pipe system rating. All samples shall hold the test pressure for a minimum of 2 min.

9.3.2 Lot Size—A lot shall consist of 20 flanges or 10 mitered fittings of any given configuration.

9.3.3 Degree of Cure—The Tg shall be determined at a minimum frequency of one test per production lot. If the measured value is more than 10°F less than the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.3.4 Glass Content—The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with Test Method D 2584. If the measured value is not within 5% of the value in the manufacturer’s specification, the lot is rejected or subject to retest.
shall be determined in accordance with Test Method D 2584. If the measured glass content is not within 5% of the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.3.5 Wall Thickness—Total wall thickness and reinforced wall thickness shall be determined in accordance with Practice D 3567 once per every production lot. Total and reinforced wall thickness shall be as specified in Table 2. Any out-of-tolerance components shall be rejected and the remainder of the lot be subject to retest.

9.4 Retest—If any test result in 9.1, 9.2, or 9.3, or combination thereof, fails to conform to the specified requirements, the manufacturer shall be permitted to elect to reject the entire lot, or retest two additional samples from the same lot. If both of the retest specimens conform to the requirements, all items in the lot shall be accepted except the sample which initially failed. If one or both of the retest samples fail to conform to the specified requirements, the manufacturer shall reject the entire lot or test individually the remaining samples in the lot in accordance with 9.1.1, 9.2.1, or 9.3.1, as applicable. Note that in the final case, all samples need only be subjected to the tests that the original samples failed.

9.5 Production Quality Documentation—The manufacturer shall have manufacturing procedures for each component to be supplied, raw material test certificates for each component to be used in manufacturing, and production quality control reports available for the procurement officer.

10. Certification

10.1 The pipe manufacturer shall be registered by an accredited agency to meet the requirements of ISO 9001. For purposes of this specification, the manufacture shall be considered a “special process” as defined in ISO 9001, Section 4.9.

11. Product Marking

11.1 Pipe and fittings shall be marked with the name, brand, or trademark of the manufacturer; NPS; manufacture date; pressure rating; pressure rating method; and other information upon agreement between the manufacturer and the purchaser.

12. Keywords

12.1 epoxy resin fittings; epoxy resin pipe; marine piping; nominal pipe size; thermoset epoxy resin pipe

APPENDIXES

(Nonnmandatory Information)

X1. DETERMINATION OF INTERNAL PRESSURE RATING FOR PIPE, FITTINGS, AND JOINTS

X1.1 Internal pressure rating for a piping system shall be determined using one of four methods. The method used to determine this rating shall be clearly identified by the manufacturer in published literature.

X1.1.1 Rating Method 1—Short-Term Test Method—Two samples of each pipe, joint, fitting, or other component shall be tested in accordance with Test Method D 1599 at ambient temperature. The maximum rating for mitered (hand lay-up) fittings shall be determined by dividing the lesser result by a safety factor of 2.5. The maximum rating for all other components shall be determined by dividing the lesser result by a safety factor of 4.0.

X1.1.2 Rating Method 2—Medium-Term (1000-h) Test—Two samples of each pipe, joint, fitting, or other component are to be tested in accordance with Test Method D 1598 for a period of 1000 h at the rated temperature. Both specimens must survive the exposure period without leakage. The maximum rating for mitered (hand lay-up) fittings shall be determined by dividing the test pressure by a safety factor of 2.0. The maximum rating for all other components shall be determined by dividing the test pressure by a safety factor of 1.87.

X1.1.3 Rating Method 3—Long-Term (10 000-h) Test—Two samples of each pipe, joint, fitting or other component are to be tested in accordance with Test Method D 1598 for a period of 10 000 h at the rated temperature. Both specimens must survive the exposure period without leakage. The maximum rating for mitered (hand lay-up) fittings shall be determined by dividing the test pressure by a safety factor of 1.5. Scaling of the results is allowed upon agreement between the manufacturer and the purchaser.

X1.1.4 Rating Method 4—Long-Term (10 000-h) Regression Test—Pipe, fittings, and joints shall be tested in accordance with Practice D 2992 Procedure B at the rated temperature. The pressure rating for all components shall be determined in accordance with the hydrostatic design basis (HDB) and lower confidence limit (LCL) as calculated in the test method. Ratings shall be determined by dividing the LCL at 20 years by a factor of 1.5. Scaling of the results is allowed for pipe bodies only in accordance with the ISO equation:

\[
S \times SF = P(D - t_r)/2t_r
\]

where:
- S = hoop stress, psi (kPa),
- SF = service factor,
- D = mean reinforced diameter (OD - t) or (ID + t), in. (mm),
- P = internal pressure psig (kPa), and
- t_r = minimum reinforced wall thickness, in. (mm).

NOTE X1.1—Liner thickness is not to be used in determining inside diameter.

NOTE X1.2—Coating thickness is not to be used in determining outside diameter.
X2. FIRE PERFORMANCE TESTS

X2.1 Fire performance tests shall be performed at an independent third-party laboratory to the satisfaction of the authority having jurisdiction.

X2.2 Piping Material Systems:
X2.2.1 All fire endurance, flame spread, and smoke and toxicity testing, where required, shall be conducted on each piping material system.
X2.2.2 Changes in either the type, amount, or architecture, or combination thereof, of either the reinforcement materials, resin matrix, liners, coatings, or manufacturing processes shall require separate testing in accordance with the requirements of this specification.

X2.3 Fire-Protective Coatings:
X2.3.1 Where a fire-protective coating is necessary for achieving the fire endurance, flame spread, or smoke and toxicity criteria, the following requirements apply:
X2.3.1.1 Pipes shall be delivered from the manufacturer with the protective coating on. On site application will be limited to what is physically necessary for installation (that is, joints).
X2.3.1.2 The fire-protection properties (that is, fire endurance, flame spread, smoke production, and so forth) of the coating shall not be diminished when exposed to (1) salt water, oil, or bilge slops, (2) other environmental conditions such as high and low temperatures, high and low humidity, and ultraviolet rays, or (3) vibration.
X2.3.1.3 The adhesion qualities of the coating shall be such that the coating does not flake, chip, or powder, when subject to an adhesion test.
X2.3.1.4 The fire-protective coating shall be resistant to impact and abrasion. It shall not be separated from the piping during normal handling.

X2.4 General Fire Endurance Test Requirements:
X2.4.1 All typical joints, including but not limited to pipe to pipe, fiberglass flange to fiberglass flange, and fiberglass flange to metallic flange intended to be used shall be tested. Elbows and tees need not be tested provided the same adhesive or method of joining utilized in straight piping tests will be used in the actual application.
X2.4.2 Qualification of piping systems of sizes different than those tested shall be allowed as provided for in Table X2.1. This applies to all pipe, fittings, system joints (including joints between metal and fiberglass pipes and fittings), methods of joining, and any internal or external liners, coverings, and coatings required to comply with the performance criteria.
X2.4.3 No alterations to couplings, fittings, joints, fasteners, insulation, or other components shall be made after the commencement of the fire endurance testing. Flange bolts shall not be retorqued after completion of the fire exposure testing, before hydrostatic testing. Postfire hydrostatic testing shall be conducted without altering the component in any way.

X2.5 Fire Type JF–Jet Fire—This test is based upon Health & Safety Executive document OTI 95 634, except that is modified so that actual pipe, joints, and fittings are exposed to the flame.

X2.5.1 Equipment:
X2.5.1.1 A propane vaporization and propulsion system capable of delivering $0.66 \pm 0.11$ lb/s ($0.3 \pm 0.05$ kg/s) flow under controlled conditions into a backing “box” which has the test specimen mounted at the box’s front opening. The nozzle shall be a tapered, converging type, 7.875 in. (200 mm) in length with an inlet diameter of 2.0 in. (52 mm) and an outlet diameter of 0.70 in. (17.8 mm). The nozzle is to be located 3.281 ft (1.0 m) from the front of the box, centered across the box, and mounted horizontally between 15 in. (375 mm) and 30 in. (750 mm) from the bottom of the box. The flow shall directly impinge on the test specimen.
X2.5.1.2 Water-handling and timing equipment suitable for delivering sufficient quantities of water to produce a fluid velocity of 3 ft/s (0.91 m/s) at the rated pressure of the piping system being tested.
X2.5.1.3 Instrumentation to record fuel flow rate, water flow rate, temperatures in the specimen and in various locations in the backing panel, and water leakage rate from the pipe assembly or individual components.
X2.5.2 Test Specimen—The test specimen shall be prepared with the joints, fittings, and fire-protection coverings, if any, intended for use in the proposed application. It is up to the authority having jurisdiction to determine the number and size of test specimens, as well as requirements for the qualification of a range of pipe diameters.
X2.5.3 Test Conditions:
X2.5.3.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature that is within 50 % relative humidity of 70 \pm 10°F (20 \pm 5°C). Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the coatings’ or coverings’ properties should not degrade over time or due exposure to the environment as discussed in IMO FTP Code Res A.753(18) Paragraph 2.2.6, or both.
X2.5.3.2 The test specimen shall be planar and shall be mounted flush to the opening of a 5 by 5-ft (1.5 by 1.5-m) open-ended, steel box (closed back panel with a depth of 1.64 ft (0.5 m). Suitable auxiliary equipment shall be attached to the box to ensure the box’s structural stability and to prevent any

### TABLE X2.1 Qualification of Piping Systems of Different Sizes

<table>
<thead>
<tr>
<th>Size Tested [NPS], in. (mm)</th>
<th>Minimum Size Approved, in. (mm)</th>
<th>Maximum Size Approved, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1.5 (0 to 40)</td>
<td>size tested</td>
<td>size tested</td>
</tr>
<tr>
<td>2 to 4 (50 to 100)</td>
<td>size tested</td>
<td>4 (100)</td>
</tr>
<tr>
<td>5 to 10 (125 to 250)</td>
<td>size tested</td>
<td>10 (250)</td>
</tr>
<tr>
<td>12 to 22 (300 to 550)</td>
<td>size tested</td>
<td>22 (550)</td>
</tr>
<tr>
<td>24 to 34 (600 to 850)</td>
<td>size tested</td>
<td>34 (850)</td>
</tr>
<tr>
<td>36 to 48 (900 to 1200)</td>
<td>size tested</td>
<td>48 (1200)</td>
</tr>
</tbody>
</table>
X2.5.3.3 If required to record temperature conditions during testing, mount thermocouples on the specimen and within the box or its structure.

X2.5.3.4 The test building shall be suitably constructed to ensure there is not a hazardous amount of heat or smoke allowed to accumulate during or after the test.

X2.5.3.5 Before conducting the test, calibration runs of the gas flow controls and water flow system shall be conducted.

X2.5.3.6 Fuel used shall be commercial grade propane delivered to the nozzle as a vapor without a liquid fraction.

X2.5.4 Test Procedure:

X2.5.4.1 Pressure test each test specimen to 1.5 times its rated pressure prior to mounting in the test rig. No leakage is allowed during this test.

X2.5.4.2 Unless Fluid S is specified, completely drain the specimen of water after the initial test and secure into position. Make all thermocouple and plumbing connections at this time. For Fluid S conditions, secure the specimen into position filled with water.

X2.5.4.3 It is acceptable to start the test using a small “pilot” flame to ensure safe ignition of the fuel before full flow being established.

X2.5.4.4 Increase the flow to the rate as specified in X2.5.1.1. This rate has been shown to produce a heat flux between 95 100 and 126 800 Btu/(h-ft²) (300 and 400 kW/m²). Timing of the test is to begin when the specimen is fully engulfed. Establish fully controlled flow within 30 s of the start of the test.

X2.5.4.5 If Fluid E or S is specified in 4.3.1, then continue the test for a minimum of 20 min under the initial conditions.

X2.5.4.6 If Fluid EF in 4.3.1 is specified, take the following steps:

1. Continue the test in the dry condition for 5 min.

2. After the 5-min dry period, introduce water at a flow velocity not to exceed 3.0 ft/s. Pressure in the system is to be maintained at a minimum of 90 % of the rated pressure for the system. These conditions are to be established within 1 min after the flow of water begins.

3. Continue the test under flowing water conditions for a minimum of 15 min.

X2.5.4.7 Increased exposure times over those previously specified are acceptable upon agreement between the manufacturer and the buyer.

X2.5.4.8 Upon completion of the fire exposure period, discontinue the fuel flow, extinguish the flame, and allow the sample to cool (with flowing water, if desired) to room temperature.

X2.5.4.9 After cooling, pressurize the specimen at it’s rated pressure for a minimum of 15 min with stagnant water (make-up water is allowed). Measure overall leakage and leakage of each component and record after this period.

X2.5.5 Acceptance Criteria—Piping shall be deemed to have passed the test if the performance meets the criteria set by the authority having jurisdiction regarding integrity and duration in 4.3.3. If no criteria is established, a maximum leakage of 10 % of the rated flow will be used as the default limit.

X2.5.6 Report—Report the following information:

X2.5.6.1 Complete identification of the pipe or fitting tested including the manufacturer’s name and code.

X2.5.6.2 Description of fire-protective coating, if applicable.

X2.5.6.3 Diameter of pipe, fitting, or joint.

X2.5.6.4 Endurance time.

X2.5.6.5 Appearance of test specimen.

X2.5.6.6 Date of test.

X2.5.6.7 Leakage rate.

X2.6 Fire Type HF—Hydrocarbon Furnace Test Method—This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications. The procedure in Test Method E 1529 with additional steps as outlined shall be followed. This procedure is similar to IMO Assembly Resolution A.753(18), Appendix 1, which is an alternative to this test.

X2.6.1 Significance—This test method is intended to provide a basis for evaluating the time period during which fiberglass pipe will continue to perform its intended function when subjected to a controlled, standardized fire exposure. In particular, the standard exposure condition of Test Method E 1529 simulates the condition of total continuous engulfment of a pipe or piping system in the luminous flame (fire plume) area of a large, free-burning hydrocarbon pool fire. The standard fire exposure is defined in terms of the total flux incident on the test specimen together with the appropriate temperature conditions.

X2.6.2 Test Equipment:

X2.6.2.1 Furnace—The setup and control of the test shall be as specified in Sections 6 through 11 of Test Method E 1529.

X2.6.2.2 Nitrogen tank with regulator or water circulating system with flow meters.

X2.6.3 Test Specimen:

X2.6.3.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature at 50 % relative humidity of 70 ± 10°F (20 ± 5°C). Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the coatings or coverings properties should not degrade over time or due to exposure to the environment as discussed in IMO FTP Code Res A.753(18) Paragraph 2.2.6, or both.

X2.6.3.2 Accelerated conditioning is permissible provided the test method does not alter the properties of component materials.

X2.6.3.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. Construct these samples in such a way as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

X2.6.3.4 Prepare the test specimen with the joints, fittings, and fire-protection coverings, if any, intended for use in the proposed application.
X2.6.3.5 The number of specimens shall be sufficient to test typical joints as noted in X2.4.1.

X2.6.3.6 For specimens to be tested using Fluid E, the ends of the specimen shall be closed with one end allowing pressurized nitrogen to be connected. Specimens to be tested with Fluid EF and S shall have both ends closed with means to connect the water supply.

X2.6.3.7 It is permissible for the pipe ends and closures to be outside the furnace.

X2.6.3.8 The general orientation of the specimen shall be horizontal and it shall be supported by one fixed support. Remaining supports shall allow free movement.

X2.6.3.9 Special samples shall be used for moisture content determination and conditioned with the test specimen. Construct these samples so as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

X2.6.3.10 When testing with Fluid E, nitrogen pressure inside the test specimen shall be maintained automatically at 10.1 ± 1.5 psi (0.7 ± 0.1 bar) during the test. Means shall be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen to indicate leakage.

X2.6.4 Procedure:

X2.6.4.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

X2.6.4.2 Place specimen in the furnace.

X2.6.4.3 Pressurize specimens to be tested with Fluid E with nitrogen maintaining the pressure in accordance with X2.6.3.10. Specimens to be tested with Fluid EF shall be initially filled with ambient air for 5 min and then with water flowing with a maximum velocity of 3 ft/s and 44 ± 7 psi (3 ± 0.5 bar). Specimens to be tested with Fluid S shall be filled with water at 44 ± 7 psi (3 ± 0.5 bar).

X2.6.4.4 Subject the piping or piping system to the fire exposure specified in Section 6 of Test Method E 1529 for the time specified by the authority having jurisdiction.

X2.6.4.5 After termination of the furnace test, allow the specimen, together with any fire-protective coating, to cool in still air to ambient temperature and then test to the rated pressure for 15 min.

X2.6.5 Acceptance Criteria—Pipe shall be deemed to pass the test if the performance meets the customer specified integrity/duration in 4.3.3. Note that, to meet IMO A753(18), Level 1 or Level 2 requirements, Fluid E shall be tested and there shall be no nitrogen leakage during the test or water leakage during the hydrotest in X2.6.4.5. For Level 1 or Level 2, the duration of the test is 60 or 30 min, respectively.

X2.6.6 Report—Report the following information:

X2.6.6.1 Complete identification of the pipe or fitting tested including manufacturer’s name and code.

X2.6.6.2 Description of fire-protective coating, if applicable.

X2.6.6.3 Diameter of pipe, fitting, or joint.

X2.6.6.4 Endurance time.

X2.6.6.5 Appearance of test specimen.

X2.6.6.6 Date of test.

X2.7 Fire Type IF–Impinging Flame:

X2.7.1 Scope—This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications. This test procedure is based on the IMO Assembly Resolution A.753(18) Appendix 2, which is an alternate procedure.

X2.7.2 Summary of Test Method—This test method subjects a pipe sample to a constant 36 011-Btu/(h-ft²) (113.6-kW/m²) net flux to determine a pipe systems fire-endurance.

X2.7.3 Test Equipment:

X2.7.3.1 Sievert No. 2942 Burner or Equivalent, which produces an air mixed flame. Propane with a minimum purity of 95 % should be used.

(1) The inner diameter of the burner heads shall be 1.14 in. (29 mm).
(2) The burner heads shall be mounted in the same plane and supplied with gas from a manifold (see Fig. X2.1).

(3) Each burner shall be equipped with a valve, if necessary, to adjust the flame height.

(4) It is acceptable to use a burner stand or pipe supports with an adjustable height.

(5) The distance between the burner heads and the pipe shall be maintained at 5 ± 3/8 in. (125 ± 10 mm) during the test.

(6) The free length of pipe between supports shall be 31.5 ± 2 in. (800 ± 50 mm).

X2.7.3.2 Thermocouples—Two thermocouples capable of measuring up to 2012°F (1100°C).

X2.7.3.3 Water.

X2.7.3.4 Thermometer, to measure internal water temperature.

X2.7.3.5 Pressure Gage, which is capable of reading up to 73 psi (5 bar) ± 5%.

X2.7.3.6 V-shaped Pipe Supports, two.

X2.7.4 Test Specimen:

X2.7.4.1 The test specimen shall be 59 in. (1.5 m) long.

X2.7.4.2 Pipe with permanent joints or fittings intended for use in marine applications shall be used in the specimen.

X2.7.4.3 All joint types shall be tested as noted in X2.4.1.

X2.7.4.4 The quantity of pipe specimens shall be sufficient to test all typical joints and fittings.

X2.7.4.5 A pressure relief valve shall be connected to one of the end closures of the system.

X2.7.5 Test Conditions:

X2.7.5.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature at 50% relative humidity of 70 ± 10°F (20 ± 5°C). Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the coatings’ or coverings’ properties should not degrade over time or as a result of exposure to the environment as discussed in IMO FTP Code Res A.753(18) Paragraph 2.2.6, or both.

X2.7.5.2 Accelerated conditioning is permissible provided the test method does not alter the properties of component materials.

X2.7.5.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. Construct these samples so as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

X2.7.5.4 The test shall be carried out in a sheltered test site to prevent any draft from influencing the test.

X2.7.5.5 Specimens to be tested with Fluid E shall be pressurized with nitrogen maintaining the pressure in accordance with Appendix X2. Specimens to be tested with Fluid EF shall be initially filled with ambient air for 5 min and then with water flowing with a maximum velocity of 3 ft/s and 44 ± 7 psi (3 ± 0.5 bar). Specimens to be tested with Fluid S shall be filled with water at 44 ± 7 psi (3 ± 0.5 bar).

X2.7.5.6 The water temperature when testing with Fluids S and EF shall not be less than 59°F (15°C) at the start of the test and shall be measured at a maximum of 5-min intervals during the test.

X2.7.5.7 Flame Temperature:

(1) The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (25 mm) from the pipe near the center span of the assembly.

(2) The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

(3) The test temperature shall be taken as the average of the two thermocouple readings.

X2.7.6 Procedure:

X2.7.6.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

X2.7.6.2 Place the specimen on two V-shaped supports. The two stands shown in Fig. X2.1 are permissible supports.

X2.7.6.3 Pressurize the specimen with water as required in accordance with Appendix X2. Specimens to be tested with Fluid EF shall not be less than 59°F (15°C) at the start of the test.

X2.7.6.4 Burner Configuration for Constant Heat Flux:

(1) For piping 6 in. or less in diameter, the fire source shall consist of two rows of 5 burners as shown in Fig. X2.2.

(2) A constant heat flux averaging 36 011 Btu/(h-ft²) (113.6 kW/m²) ± 10% shall be maintained 5 ± 3/8 in. (125 ± 10 mm) above the centerline of the array.

(a) This flux corresponds to a premix flame of propane of a minimum 95% purity with a fuel flow rate of 11.02 lb/h (5 kg/h) for a total heat release of 221 780 Btu/h (65 kW).

(b) The gas consumption shall be measured with an accuracy of ±3% in order to maintain a constant heat flux.

(3) For piping greater than 6 in. in diameter, one additional row of burners shall be included for each 2-in. increase in diameter while maintaining the heat flux in X2.7.6.4.

(4) Begin the heat flux.

(5) Record the test temperature and water temperature and pressure, if applicable, at the beginning of the test, at the end of the test, and at maximum 5-min intervals during the test.
X2.7.6.5 Expose the test specimen to flame for 30 min.
X2.7.6.6 After termination of the burner regulation, test the test sample, together with the fire-protective coating, if any, shall be allowed to cool to ambient temperature and then tested to the rated pressure of the pipe. If fire-protective coverings are used, then conduct the pressure test without the covering, where practical.

(1) Hold the pressure for a minimum of 15 min.

X2.7.7 Acceptance Criteria—Piping shall be deemed to have passed the test if the performance meets the criteria set by the authority having jurisdiction regarding integrity and duration in 4.3.3.

X2.7.8 Report—Report the following information:
X2.7.8.1 Complete identification of the pipe or fitting tested including the manufacturer’s name and code.
X2.7.8.2 Description of fire-protective coating, if applicable.
X2.7.8.3 Diameter of pipe, fitting, or joint.
X2.7.8.4 Endurance time.
X2.7.8.5 Appearance of test specimen.
X2.7.8.6 Date of test.
X2.7.8.7 Leakage rate.

X2.8 Flame Spread:
X2.8.1 Flame spread testing of fiberglass piping shall be conducted in accordance with Appendix 3 of IMO Resolution A.753(18) except as modified in X2.8.2.
X2.8.2 Testing need not be conducted on all piping sizes. Only the sizes with the maximum and minimum wall thickness to be used must be tested.

X2.9 Smoke and Toxicity:
X2.9.1 Smoke and toxicity testing of fiberglass piping shall be conducted in accordance with Annex 1, Part 2—Smoke and Toxicity Test, of IMO Resolution MSC.61(67) except as modified in X2.9.2-X2.9.12. These modifications are similar to those in Appendix 3 of IMO A.753(18) except they apply to the smoke and toxicity test, not the surface flammability test.
X2.9.2 Testing shall be conducted on piping sizes with the maximum and minimum wall thickness intended to be used.

X2.9.3 The test sample shall be fabricated by cutting pipes lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. All cuts shall be made normal to the pipe wall.
X2.9.4 The number of sections that must be assembled together to form a square test sample with sides measuring 3 in. shall be that which corresponds to the nearest integral number of sections which will result in a test sample with an equivalent linearized surface width between 3 and 3.5 in. The surface width is defined as the measured sum of the outer circumference of the assembled pipe sections normal to the lengthwise sections.
X2.9.5 The assembled test sample shall have no gaps between individual sections.
X2.9.6 The assembled test sample shall be constructed in such a way that the edges of two adjacent sections will coincide with the centerline of the test holder.
X2.9.7 The test samples shall be mounted on calcium silicate board and held in place by the edges of the test frame and, if necessary, by wire.
X2.9.8 The individual pipe sections shall be mounted so that the highest point of the exposed surface is in the same position as the plane of an equivalent flat plate.
X2.9.9 The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board shall be left void.
X2.9.10 The void space between the top of the exposed test surface and the bottom edge of the sample holder frame shall be filled with a high-temperature insulating wool where the pipe extends under the frame.
X2.9.11 When the pipes are to include fireproofing or coatings, the composite structure consisting of the segmented pipe wall and fire proofing shall be tested and the thickness of the fireproofing shall be the minimum thickness specified for the intended usage.
X2.9.12 The test sample shall be oriented in the apparatus such that the pilot burner flame will be normal to the lengthwise piping sections.

X3. ELECTRICAL PROPERTY TEST METHODS FOR CONDUCTIVE FIBERGLASS PIPING

X3.1 Test Method for Determination of Charge Shielding Properties of Reinforced Thermo-setting Resin Pipe, Fittings, and Joints:

X3.1.1 Summary of Test Method—In this test method, a high-voltage electric field is applied to the interior surface of a grounded reinforced thermosetting resin pipe, fitting, or joint, and the resulting voltage on the exterior surface, if any, is measured. This test can also be used to determine the effect of typical chemical exposure on the conductive properties of the pipe, fittings, and joints.
X3.1.2 Test Equipment:
X3.1.2.1 DC Supply, capable of producing a minimum voltage of 1000 V.
X3.1.2.2 Fieldmeter, capable of measuring and displaying electric fields values of 100 V·m⁻¹ with zero stable within 50 V·m⁻¹ over at least 1000 s. A reading of 100 V·m⁻¹ shall be at least 10% of an analog scale reading or at least the second digit of a digital display. The instrument display shall give a linear response to electric field, symmetric with polarity and with no hysteresis. These properties shall be within 5% of full-scale reading of the operating range. The output time constant at the display shall be less than 1 s.
X3.1.3 Sample Preparation:
X3.1.3.1 The minimum NPS of the pipe, fitting, or joint tested shall be 2.
X3.1.3.2 For pipe specimens, the minimum length of the sample shall be seven times the NPS.
X3.1.3.3 If necessary to provide space for a grounding clamp, add further sections of conductive pipe, as necessary, to the specimen using the manufacturer’s normally recommended assembly methods for conductive joints. If a joint is required, then the resistance across the joint shall be determined in accordance with X3.2.
X3.1.3.4 Identify a minimum of five locations on the outside of the component for positioning the fieldmeter. Ensure that the locations around the periphery are equally spaced over the length of the component. It is possible that additional locations are needed to account for regions where there is a change in component geometry.

X3.1.4 Conditioning:
X3.1.4.1 The test specimen shall not be tested until the material has reached an air-dry condition. This condition is defined as 16 to 24 h at an ambient temperature of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity.
X3.1.4.2 If the effect of the environment on the electrical properties is required, place the specimens in a test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 60 to 80°F (15 to 27°C) throughout the test.

(1) At the end of three months, remove the test specimen from the tank and rinse thoroughly with tap water if the specimen has been exposed to a water-soluble product or a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

(2) Wipe dry and place the test specimen in an oven at 149 ± 10°F (65 ± 5°C) for a period of 2 h.

(3) Remove the specimen from the oven and allow it to cool to 70 to 80°F (21 to 27°C) in a 50 ± 5 % relative humidity environment for 16 to 24 h.

X3.1.5 Procedure:
X3.1.5.1 Install a grounding clamp of the earthing system on the exterior of the specimen at each end of the component in accordance with the manufacturer’s instructions. Any surface preparation shall not exceed that normally required when installing a piping system.

X3.1.5.2 Blank off each termination of the specimen assembly with a suitable removable plug made from an insulating material which is in contact with just the inside surface of the component. One of the plugs shall be provided with an electrode that passes through the thickness of the material. For fittings, this electrode shall be a minimum distance of 12 in. (305 mm) away from the main body of the fitting. An additional section of conductive pipe shall be added as necessary to the component in accordance with X3.1.3.3.

X3.1.5.3 Completely fill the inside of the specimen with a suitable conducting fluid. It is acceptable to fit one or more of the plugs with a vent fitting to enable air to be expelled. Ensure the outside of the specimen is dry.

X3.1.5.4 Position the specimen vertically on a nonconducting surface or suspend it with non-electrically conducting materials in a manner to ensure that the outside of the component under test is accessible on all sides. The plug with the electrode shall be positioned such that the inside is in contact with the conducting fluid.

X3.1.5.5 Connect the electrode in the plug to the dc supply.
X3.1.5.6 Position the fieldmeter 1 in. (25 mm) from the exterior surface of the component under test. The fieldmeter shall be a minimum distance of 12 in. (305 mm) away from the wire connecting the dc supply to the electrode in the plug.

X3.1.5.7 With the specimen connected to earth using the grounding clamp, turn the dc supply on and monitor the output of the fieldmeter for 1 min. Turn off the dc supply.

X3.1.5.8 Repeat X3.1.5.6 and X3.1.5.7 for the remaining test positions.

X3.1.6 Report—Report the following information:
X3.1.6.1 Manufacturer of pipe, fitting, or joint.
X3.1.6.2 Designation of the product being tested.
X3.1.6.3 Description of the test sample including diameter of pipe, fitting, or joint and lengths of pipe extenders, if used.
X3.1.6.4 Description of grounding details.
X3.1.6.5 Test media if exposure is done.
X3.1.6.6 Conducting fluid used.
X3.1.6.7 dc supply voltage.
X3.1.6.8 Record of voltage output from the fieldmeter for 1 min for each test position and after exposure for one, three, six, and twelve months when exposure testing is done.
X3.1.6.9 Appearance of test specimen.
X3.1.6.10 Date.

X3.2 Test Method for Determining the Electrical Resistance Per Unit Length of Fiberglass Pipe, Fittings, Joints, and Representative Piping Systems:

X3.2.1 Summary of Test Method—In this test method, the length of the potential current path is measured and then the resistance is determined using a suitable megohmmeter capable of measuring resistance between 2000 and 1 × 10¹⁰ Ω. The test method is also useful to determine the effect of typical chemical exposures on the conductive properties of the pipe. The results are expressed in terms of resistance per unit length.

X3.2.2 Test Equipment:
X3.2.2.1 Megohmmeter, capable of measuring resistance between 2000 and 1 × 10¹⁰ Ω with a resolution of 5 %. The voltage between the electrodes shall be a minimum of 500 V.

X3.2.3 Test Specimen:
X3.2.3.1 Pipe.

(1) The pipe length shall be 3.28 ft (1 m) or six times the nominal diameter of the product plus two times the width of the grounding clamps, if applicable, whichever is greatest.

X3.2.3.2 Pipe with Fitting or Joint, or Both:

(1) NPS 2 piping shall be used unless otherwise specified.

(2) The electrical construction of the pipe shall be consistent with that of the fitting and joint.

(3) The joint or fitting shall be attached to two lengths of pipe. It is possible that this will require some fittings, for example, flanges, to be assembled in pairs. The length of each pipe shall be six times the nominal diameter of the product plus one times the width of the grounding clamps, if applicable. If needed to achieve this length, add further sections of conductive pipe using the manufacturer’s recommended assembly methods.
X3.2.4 Conditioning—The test specimen shall not be tested until the material has reached an air-dry condition. This condition is defined as 16 to 24 h at an ambient temperature of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity.

X3.2.5 Procedure:

X3.2.5.1 Where the electrical conductivity properties of the pipe and joint/fitting combination is to be evaluated, first determine the electrical properties of the pipe on its own.

X3.2.5.2 Current Path Selection—The current paths of interest are as follows:

1. Inside surface of the pipe at one end of the test assembly to the outside surface of the pipe at the other end of test assembly.
2. Outside surface of the pipe at one end of the test assembly to the outside surface of the pipe at the other end of test assembly.

X3.2.5.3 Sample Preparation:

1. Attach a suitable electrode (see Note X3.1) or grounding clamp to the outside diameter of a pipe on one end of the pipe or assembly.
2. Where a grounding clamp is applied, the surface preparation shall not exceed that used when piping systems are installed in accordance with the manufacturer’s recommendations.

3. Apply two suitable electrodes, one around the interior circumference of the specimen and one around the exterior circumference, on the other end of the pipe or assembly. Where the test is being carried out to confirm continuity of the embedded conducting elements within the component body, it is permissible to use the exterior electrode as a grounding clamp that is applied in a similar manner to the first.

4. The distance of the electrodes from the end of the specimen shall be greater than or equal to twice the specimen thickness. The width of the electrodes shall be between four and six times the specimen wall thickness.

Note X3.1—A suitable electrode shall provide the necessary conductivity to the surface of the pipe without causing damage to the surface. Examples include conductive paints, conductive adhesive tape, and brine-soaked sponges held in place with clamps.

X3.2.5.4 Outside-to-Outside Surface Electrical Measurement:

1. Isolate the test specimen from ground.
2. Attach suitable wires to the external electrodes.
3. Determine the resistance using the megohmmeter.
4. The power applied neither should exceed 3.41 Btu/h (1W), and the electrification time shall not exceed one minute unless otherwise specified. Record the readings from the megohmmeter and its accuracy at that range.
5. If the effect of the environment on the electrical properties is required, place the specimens in the test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 59 to 80°F (15 to 27°C) throughout the test. At the end of three months, remove the test specimen from the bath and rinse thoroughly with tap water if the specimen has been exposed to a water soluble product or a hydrocarbon solvent if the specimen has been exposed to a petroleum product. Wipe dry and place the test specimen in an oven at 149 ± 9°F (65 ± 5°C) for a period of 2 h. Remove the specimen from the oven and allow it to cool to 70 to 80°F (21 to 27°C) in a 50 ± 5 % relative humidity environment for 16 to 24 h. Determine the resistance using the megohmmeter. Note the appearance of the test specimen and the condition of the clamps.

X3.2.5.5 Inside-to-Outside Surface Electrical Measurement:

1. Isolate the test specimen from ground.
2. Attach suitable wires to the internal and external electrode.
3. Carry out the procedure in accordance with X3.2.5.4.

X3.2.6 Calculation of Pipe and Joint/Fitting Electrical Resistance:

X3.2.6.1 The electrical resistance shall be calculated for the two cases:

1. External-to-external surface of the component.
2. External-to-internal surface of the component.

X3.2.6.2 Care shall be taken to ensure that these two situations are treated separately.

X3.2.6.3 For the pipe tested on its own, the resistance per unit length of pipe shall be calculated by dividing the resistance of the pipe by the length between electrodes.

X3.2.6.4 The resistance of the fitting or joint shall be calculated as follows:

1. Calculate the resistance of each length of pipe attached to the joint or fitting by multiplying the resistance per unit length by the distance from the electrode to the fitting/joint.
2. Subtract two times the pipe resistance from the overall resistance measured across the assembly to give the resistance across the coupling.

X3.2.6.5 The resistance per unit length shall be determined by dividing the resistance by the effective path length. The effective path length depends on the type of fitting and mode tested.

X3.2.6.6 For pipes, straight joints, adapters, couplings, plugs, caps, and bushings, the path length shall be parallel to the centerline axis of the component and shall encompass the length of the component.

X3.2.6.7 For elbows, the path length shall be the length of the component at the mid-bend radius.

X3.2.6.8 For crosses and tees, one path length shall be parallel to the centerline axis of the component and shall encompass the length of the component. The other path length shall be along the shortest path from adjacent openings through each 90° bend.

X3.2.6.9 For laterals, one path length shall be parallel to the centerline axis of the component and shall encompass the length of the component. The second path length shall be along the shortest distance between adjacent openings through the oblique angle. The third path length shall be along the shortest distance between adjacent openings through the obtuse angle.

X3.2.7 Report—Report the following information:

X3.2.7.1 Complete identification of the pipe and fitting/joint/fire-protection coating tested including the manufacturer’s name and code.

X3.2.7.2 Diameter of the pipe, fitting, or joint.

X3.2.7.3 Details of the megohmmeter including name and model number, resolution capability, and voltage applied.
X3.2.7.4 Mode of testing, that is, external surface-to-
external surface or external surface-to-internal surface and
whether grounding clamps were used.
X3.2.7.5 Results of testing:
(1) Resistance per unit length of pipe.
(2) Resistance of fitting/joint.
X3.2.7.6 Environmental exposure time and media where
applicable.
X3.2.7.7 Appearance of specimen.
X3.2.7.8 Date of test.

X4. SUPPLEMENTARY REQUIREMENTS FOR U.S. NAVY USE

X4.1 Scope—This appendix shall be applied only when
specified by the purchaser in the inquiry, contract, or order.
This appendix contains special material, design, and perfor-
mance considerations and supplemental tests required when
fiberglass piping is to be used for U.S. Navy applications.
These requirements shall in no way negate any requirement of
the specification itself.

X4.2 Special Material, Design, and Performance Consid-
erations:

X4.2.1 Unless otherwise specified in the ordering informa-
tion, fiberglass pipe and fittings shall be rated for a minimum
of 200-psig static pressure at a minimum of 150°F.

X4.2.2 Physical Properties—Pipe and fittings shall have the
physical properties outlined in this section. Unless otherwise
specified in the ordering information, all physical properties
shall be determined at no less than 75°F.

X4.2.2.1 Cyclic Pressure Strength—Pipe, fittings, and ad-
hesive bonded joints shall be cycled a minimum of 10 000
cycles with no signs of leakage or weeping when tested in
accordance with X4.3.2.

X4.2.2.2 Hydrostatic Strength—Pipe, fittings, and joints
shall show no signs of leakage or weeping when tested in
accordance with X4.3.3.

X4.2.2.3 Ultimate Tensile Strength—The minimum longitudi-
nal tensile strength of sample pipe shall be 8500 psi at 75°F
or higher when tested in accordance with Test Method D 2105.

X4.2.2.4 Beam Elastic Modulus—The minimum elastic
modulus of pipe shall be 1 000 000 psi at 150°F when
determined in accordance with Specification D 5686.

X4.2.2.5 Hydrostatic Burst Strength—The minimum hoop
tensile strength of pipe shall be 30 000 psi at 75°F when tested
in accordance with Test Method D 1599.

X4.2.2.6 Low-Cycle Mechanical Fatigue—Piping assem-
blies shall successfully pass the mechanical fatigue test out-
lined in X4.3.3.4 with no visible signs of leakage.

X4.2.3 No asbestos is permitted in the construction of pipe
or fittings.

X4.3 Supplemental Test Methods—Supplemental test meth-
ods shall be conducted at a laboratory satisfactory to the
customer and shall consist of the following test methods.

X4.3.1 Cyclic Pressure Strength—Test specimens shall in-
clude a tee, a flange, and one other fitting selected by the
supplier. The fitting shall be joined to pipe sections at least 18
in. long or three diameters, whichever is longer, using the
joining method, construction, and adhesion intended for field
assembly. Specimen diameters for testing in each configuration
shall include the maximum product size for each method of
construction. In addition, the following other sizes shall be tested:

<table>
<thead>
<tr>
<th>Product Size Range (NPS)</th>
<th>Test Specimen (NPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 1 1⁄2, 2, 3</td>
<td>3</td>
</tr>
<tr>
<td>4, 6</td>
<td>6</td>
</tr>
<tr>
<td>8, 10, 12</td>
<td>12</td>
</tr>
</tbody>
</table>

In each range of product size, the supplier is permitted to
select to test a smaller product size to qualify only the smaller
size. Each assembly shall be cycled at pressures between 0 psig
and two times the static pressure rating for a minimum of
10 000 cycles without failure. Failure shall be classified as any
leakage or weeping from the pipe, fitting, or joint.

X4.3.2 Hydrostatic Strength—Test specimens shall include
a tee, a flange, and one other fitting selected by the supplier.
The fitting shall be joined to pipe sections at least 18 in. long
or three diameters, whichever is longer, using the joining
method, construction, and adhesion intended for field assem-
blies. Specimen diameters for testing in each configuration
shall include the maximum product size for each method of
construction. In addition, the following other sizes shall be tested:

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In each range of product size, the supplier is permitted to
select to test a smaller product size to qualify only the smaller
size. Each assembly shall be subjected to a pressure of two
times the static pressure rating for 5 min, followed by a
pressure drop to 0 psig, and then a repressurization to four
times the static pressure rating for a minimum of 5 min.

X4.3.3 Low-Cycle Mechanical Fatigue Endurance Test
Method—The purpose of this test method is to verify the
integrity of the piping system when it is subjected to external
mechanical fatigue loads and to demonstrate adequate pipe
fatigue endurance under cyclic mechanical loading. The load
values for this test have been derived from past successful
performance in marine applications.

X4.3.3.1 This test method shall be performed on 1, 3, and 6
NPS assemblies which will qualify piping up to 8 NPS. If
qualification for only one size is required, the supplier is
permitted to test that size.

X4.3.3.2 A test assembly and apparatus shall be fabricated
as shown in Fig. X4.1. The assembly shall consist of a flange,
a vertical leg of pipe with a coupling at midspan, a 90º elbow,
and a horizontal leg of pipe terminating at a second flange. The
total length of the vertical leg from the base of the flange to the
centerline of the horizontal leg shall be 10 to 15 times the
nominal pipe diameter. The total length of the horizontal leg
from the centerline of the cycling arm to the vertical leg shall
be one half of the vertical leg length. Fittings shall be attached to the pipe using the joining method, construction, and adhesion intended for field assembly. If more than one type of fitting (that is, Type I and III in accordance with 4.1.1) is intended for qualification, then each type of fitting must be represented.

X4.3.3.3 The fiberglass pipe assembly shall be fitted with a minimum of six strain gages in the following locations on the “outside” of the vertical leg (the side of the pipe which is subjected to tensile stress/strain when the horizontal leg is displaced downward):

1. Within 1/2 in. of the bottom flange.
2. Within 1/2 in. of the top of the coupling.
3. Within 1/2 in. of the bottom of the coupling.
4. Within 1/2 in. of the 90° elbow.
5. Midway between the coupling and the 90° elbow.
6. Midway between the coupling and the bottom flange.

These locations are shown in Fig. X4.1. All gages are to be mounted in-line, to within $\pm 6^\circ$, with the vertical pipe axis to measure axial strain along the vertical pipe leg. The surface of the pipe wall shall be lightly sanded to remove surface roughness at the gage location before installing the gages.

Note X4.1—The following procedure for fully reversed bending ignores (1) the effect of Poisson’s ratio as a result of pressure in calculating the axial stress at the pipe wall and (2) the effect of internal pressure on the mean stress of the pipe wall during fully reversed bending. A further simplification assumes that the bending modulus of the pipe is equal to the axial tensile modulus.

X4.3.3.4 After the pipe assembly has been mounted in the test apparatus, adjust the apparatus so that the assembly is subjected to a stress of 7000 psi. This is done in the following manner:

1. Pressurize the pipe assembly to 50 (±0/−5) psig.
2. Actuate the hydraulic cylinder and displace the horizontal leg of the pipe assembly down to load the vertical pipe leg containing the strain gages under tension.
3. Adjust the displacement of the pipe assembly until the average of all the strain gages indicates an axial strain corresponding to a pipe wall stress of 7000 psi. The axial tensile stress can be approximated by multiplying the strain reading by the pipe’s axial tensile modulus and ignoring Poisson’s effect because of pressure.

4. (4) Record the strain gage reading and note the actuator displacement.

5. (5) Reverse the displacement by moving the horizontal leg of the pipe assembly up until the gages registers the equivalent absolute value of stress under compression as previously registered under tension.

6. (6) Calculate the compressive stress and note the actuator displacement.

X4.3.3.5 Mechanically limit or fix the actuator displacements in the UP and DOWN directions to correspond to the stress values of 7000 psi tensile and 7000 psi compressive.

X4.3.3.6 Begin cycling the actuator and verify that the average of the axial-tensile and compressive strains are repeated at least three times to within $\pm 2\%$.

X4.3.3.7 Cycle the pipe assemblies under fully reversed bending at a rate no greater than 15 cycles per minute for a minimum of 500 cycles or until failure. Failure is defined as the smallest detectable leak, including weeping, from the pipe assembly. Experience has shown that failure often occurs at the strain gage location where the pipe surface has been lightly sanded. Pipe wall weeping which occurs under maximum stress but stops under reduced stress is still a failure. Any leak from a fitting or adhesive-bonded joint shall constitute a failure. It is likely that all failures will occur in the pipe wall. Note that if data is used from any one test assembly cycled to failure, then all assemblies must be cycled to failure to generate consistent results for graphical plotting and extrapolation.

X4.3.3.8 Record the number of cycles to failure for each size of pipe assembly.

X4.3.3.9 Repeat the procedure with an equivalent stress of 6000 psi with a minimum of 2000 cycles.

X4.3.3.10 Repeat the procedure with an equivalent stress of 4000 psi with a minimum of 50 000 cycles.
X4.3.3.11 Plot the stress versus cycles to failure data on a log-log graph and generate the best-fit straight line through the data using the “least squares” method. It is permissible to extrapolate the data linearly to 100 and 100,000 cycles. The graph shall cover stress from 100 to 10,000 psi and cycles to failure from 100 to 100,000 cycles.

X4.3.3.12 The graphed line must be coincident with or above the following stress values: 6000 psi at 1000 cycles; 4500 psi at 10,000 cycles; and 3400 psi at 100,000 cycles. If the graphed line does not meet these criteria, the test specimen shall be considered to have failed the test.

This standard is issued under the fixed designation F 1178; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the performance of a baking primer and enamel on metal for use on fabricated metal products, including marine furniture and joiner work.

1.2 The values stated in inch-pound units are to be regarded as standard. The metric (SI) units, given in parentheses, are for information only.

1.3 Painting facilities shall comply with all applicable Federal and State regulations regarding emissions and waste disposal.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 1008 Specification for Steel, Sheet, Cold-Rolled, Carbon Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability
A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
B 117 Practice for Operating Salt Spray (Fog) Apparatus
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings
D 1186 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
D 3359 Test Methods for Measuring Adhesion by Tape Test
D 3363 Test Method for Film Hardness by Pencil Test
2.2 American Institute of Steel Construction Manual:
AISC Wire and Sheet Metal Gages—Equivalent Thickness in Decimals of an Inch, U.S. Standard Gauge (USSG) for Uncoated Hot and Cold Rolled Sheets and Galvanized Sheet Gage (GSG) for Hot-Dipped Zinc Coated Sheets
2.3 Code of Federal Regulations:
40 CFR 60 Subpart EE—Standard of Performance for Surface Coating of Metal Furniture

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 air dry touch-up enamel—an air drying enamel that matches the factory applied enamel in color and gloss and is compatible with it.
3.1.2 baking finish—an enamel that requires baking at temperatures above 150°F (65°C) for the development of desired properties.
3.1.3 blister—an enclosed raised spot on the paint surface caused by moisture or solvent trapped under the surface.
3.1.4 cleaning—the first phase of the metal pretreatment prior to painting.
3.1.5 cure—to condense or polymerize a material by heating, resulting in the full development of desired properties.
3.1.6 degreasing—See cleaning.
3.1.7 dry film thickness (DFT)—the actual thickness of the cured paint system. It is measured in mils or thousandths of an inch (0.001 in. or 25.4 µm).
3.1.8 Enamel—a paint characterized by the ability to form an especially smooth film.

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.01 on Structures.
2 Annual Book of ASTM Standards, Vol 01.03.
3 Annual Book of ASTM Standards, Vol 01.06.
4 Annual Book of ASTM Standards, Vol 03.02.
5 Annual Book of ASTM Standards, Vol 02.02.
6 Annual Book of ASTM Standards, Vol 06.01.
7 Available from the American Institute of Steel Construction, 400 N. Michigan Avenue, Chicago, IL 60611.

3.1.10 gloss—the degree to which a painted surface reflects light.

3.1.11 joiner work—doors, frames, ceilings, bulkheads, window casings, and all trim pieces in accommodation spaces aboard ship.

3.1.12 low gloss—finish that shows a gloss of 25 to 35 when measured with 60° glossmeter. A ceiling gloss is 6 to 16 when measured the same way.

3.1.13 pretreatment—usually restricted to mean the chemical treatment of unpaired surfaces before painting.

4. Ordering Information

4.1 Unless otherwise specified, a smooth, low-gloss enamel finish will be applied.

4.1.1 Color of enamel top coat.

4.1.2 Finish:

4.1.2.1 Smooth.

4.1.2.2 Textured.

4.1.3 Gloss (measured with 60° glossmeter):

4.1.3.1 Low gloss—25 to 35.

4.1.3.2 Ceiling gloss—6 to 18.

5. Materials and Manufacture

5.1 Metal substrate—This specification is intended for use on metal furniture and joiner work of either steel or aluminum.

5.2 For a smooth, low-gloss finish, the furniture or joiner work manufacturer shall follow the procedures in the order and as listed in Sections 6 through 7.

5.3 If a textured finish is specified, the furniture or joiner work manufacturer shall follow the procedures in the order and as listed in Sections 6 through 8.

6. Cleaning and Degreasing

6.1 All exterior and interior surfaces, both visible and concealed, and all joints shall be thoroughly cleaned and degreased.

6.2 The cleaning/rinsing process shall remove dirt, oil grease, moisture, and other foreign matter.

6.3 No detrimental residue from this process shall remain deposited on any surface.

7. Enameling

7.1 All surfaces contributing to the appearance of the final product shall be enamaled to a smooth, low-gloss finish in colors specified in the ordering documents.

7.2 Enamel shall be applied in an amount sufficient to produce a minimum dry film thickness of 1.5 mils (0.0015 in. (38.1 µm)) for joiner doors and frames. For other joiner materials and furniture, 1 to 1.5 mils (0.001 to 0.0015 in. (25.4 to 38.1 µm)) is acceptable.

7.3 The enamel required under this specification shall be a thermosetting type, requiring a high baking schedule for proper cure. This enamel shall satisfy the requirements of Section 9.

8. Texturing (Optional)

8.1 If a textured finish is required by ordering documents, the enamel chosen shall be capable of producing a suitable raised textured finish when using equipment and techniques recommended by the manufacturer.

8.2 All requirements for enameling of the textured finish shall remain as written for the smooth, low-gloss finish except that the gloss shown in 9.2.3.2 shall be 6 minimum to 16 maximum for ceiling panels. Other items may vary according to paint specified.

9. Performance Criteria

9.1 Test Panel Description—Test panels shall be 4½ in. (114 mm) minimum width and 7½ in. (191 mm) maximum length of material and thickness as listed below:

9.1.1 Cold rolled steel sheet, in accordance with Specification A 1008, USSG 20 gauge (0.0359 in. or 0.91 mm) thick.

9.1.2 Galvannealed steel sheet, in accordance with Specification A 653/A 653M with coating designation A 01, CSG 20 gauge (0.0396 in. or 1.01 mm) thick.

9.1.3 Type 5052-H32 aluminum alloy, in accordance with Specification B 209, 0.040 in. (1.02 mm) thick.

9.2 Prepare test panels for testing, test, and evaluate in accordance with the following requirements:

9.2.1 Dry Film Thickness—Measure the total dry film thickness, either prime coat or prime coat plus enamel, on metal test panels or products in accordance with Test Method D 1400. Where only steel products are being enamelled, the dry film thickness may be measured in accordance with Test Methods D 1186.

9.2.2 Primer:

9.2.2.1 Preparation of Primer Test Panels—Clean, pretreat, and coat two metal test panels with primer on both sides and on all edges in the production cycle. After baking the primed test panels, scribe one side of each panel with two diagonal scribe lines that extend through the prime coat down to the base metal. For scribing, use a sharp instrument and a suitable straightedge. Hold the scribing tool perpendicular to the surface of the test panel, and make two intersecting diagonal marks. Begin each scribe line at a point approximately 1/2 in. (13 mm) from a corner and continue to a point approximately 1/2 in. (13 mm) from the diagonally opposite corner. The scribe must penetrate the prime coating down to the metal, leaving a uniformly bright line.

9.2.2.2 Salt Spray Exposure of Primer Test Panels—Expose the metal panels in accordance with Practice B 117 for 250 h at 95°F (35°C). Remove test panels from the salt spray cabinet and rinse them using a gentle stream of water at a temperature of 100 ± 10°F (37.8 ± 5.5°C). Dry the test panels and vigorously scrape the scribed side of each panel with a dull knife blade or a suitable piece of sheet metal having a similar dull edge. Hold the scraper with its face perpendicular to the specimen surface and parallel to the scribe, moving it back and forth across the scribed line. Complete the scraping within 15 min of the drying of the surface. Masking tape, 1 in. (25 mm) wide, shall be pressed onto all scribed marks and pulled away clearly. Evaluate the performance of these test panels per 9.2.2.3 and 9.2.2.4.
9.2.2.3 Evaluation of the Blistering Resistance of Primer Test Panel—There shall be no evidence of blistering of these primed metal panels after 250-h exposure in accordance with Practice B 117.

9.2.2.4 Evaluation of the Corrosion Resistance of Primer Test Panel—Measure creepage, or loss of adhesion due to corrosion, at the scribe marks. This creepage shall not extend more than \( \frac{1}{8} \) in. (3.2 mm) on either side of scribe mark. The total width of gap in prime coat shall not exceed \( \frac{1}{4} \) in. (6.4 mm).

9.2.3 Enamel:

9.2.3.1 Preparation of Enamel Test panels—Clean, pretreat, and coat two metal test panels with primer and enamel in the production cycle to a total dry film thickness of 1 to 1.5 mils (0.001 to 0.0015 in. (25.4 to 38.1 µm)).

9.2.3.2 Gloss—The enamel test panel shall show a gloss of 25 minimum to 35 maximum when measured using a 60° glossmeter (Gardner, Photovolt, or equal) unless otherwise specified in ordering documents or, if a textured finish, gloss shall be as noted in 8.2.

9.2.3.3 Hardness—Conduct this hardness test in accordance with Test Method D 3363 using a standard 2H drafting pencil sharpened to expose the full diameter of the pencil lead. The lead is sanded to a blunt-ended but sharp-edged shape by using sanding strokes perpendicular to the centerline of the lead. Holding the end of the pencil lead firmly against the enamel test panel, with the pencil centerline at an angle of 45° with the painted surface, apply four gouging or scraping strokes to the enameled surface. The strokes shall be a minimum of \( \frac{1}{4} \) in. (6.4 mm) long and applied forward, trying to gouge the lead into the enameled surface. The enamel surface shall remain undamaged when subjected to this test.

9.2.3.4 Paint Cure—The solvent cure test determines if the enamel finish is properly cured. Conduct the test as follows: Wrap finger in a rag and dip in a solvent recommended by the manufacturer of the touch-up enamel, one or more coats as required. Wipe surface clean of dust or moisture.

9.2.3.5 Adhesion—Evaluate adhesion between enamel and prime coat and between prime coat and steel substrate by a cross-hatch test in accordance with Test Methods D 3359 and as follows: Scribe the enameled test panel with a sharp knife or similar instrument to give a cross hatch pattern with overall size of 1 in.\(^2\) (6.45 cm\(^2\)). Make 17 parallel cuts at about 1⁄16 in. (2 mm) spacing and extending through the coating to the base metal. Make 17 similar cuts at 90° to and crossing the first 17, giving a cross-hatched area of 256 squares. Press masking tape 1 in. (25 mm) wide firmly onto the entire hatched area and then immediately jerk cleanly away from the panel. Examine the hatched area. Normally, no paint squares will belifted by this test, but a classification of 3B, in accordance with Test Methods D 3359, for one panel out of three is permissible.

9.2.3.6 Flexibility—Test the enameled metal test panel for flexibility of the paint system by bending 180° over a conical mandrel in accordance with Test Method D 522. The paint system shall not flake or exhibit loss of adhesion during this test. Slight cracking of paint finish, less than \( \frac{1}{4} \) in. (6.4 mm) long, at conical mandrel diameters less than \( \frac{1}{2} \) in. (12.7 mm) is permissible.

9.2.3.7 Impact Resistance —The enameled metal test panel shall withstand a minimum of 40 in. lb (4.52 J) direct impact without cracking or loss of adhesion. The impact test consists essentially of a 2 lb (0.91 kg) bar dropping 20 in. (508 mm) onto a \( \frac{1}{2} \) in. (12.7 mm) diameter sphere in contact with the test panel. The surface of the test equipment beneath the test panel shall have a circular, concave surface greater than \( \frac{1}{2} \) in. in diameter directly under the point of contact.

9.2.3.8 Color Stability—The enameled metal test panel, when subjected to an additional bake of 350°F (177°C) for 30 min, shall show no significant change in color or gloss.

9.2.4 Air Dry Touch-Up Enamel:

9.2.4.1 Conditions for Use—This air dry touch-up enamel is intended for use in the field for minor scratches or defects only. It shall be compatible with, and adhere to, the scratched surface.

9.2.4.2 Preparation of Scratched Surface—Where appearance is important, use fine sandpaper and taper edges of scratch to blend in and conceal scratch before applying touch-up enamel. Wipe surface clean of dust or moisture.

9.2.4.3 Application—Apply by brush, roller, or spray, as recommended by the manufacturer of the touch-up enamel, one or more coats as required.

9.2.4.4 Color—Color must match the color of the scratched surface.

9.2.4.5 Gloss—Gloss must match the gloss of the scratched surface. The gloss shall be as follows, when measured with a 60° glossmeter:

- Furniture and metal joiner work: 25 to 35
- Ceiling panels: 6 to 16

9.2.4.6 Curing Rate—Cure this touch-up enamel as follows:

- Dust free: 30 min
- Dry enough to handle: 1–2 h
- Dry enough to sand and recoat: 24 h

10. Quality Assurance

10.1 Daily Test Panels—(NOTE):

10.1.1 Prepare four test panels of each of the following three metals daily: USSG 20 gage (0.0359 in. or 0.91 mm) thick cold-rolled carbon steel in accordance with Specification A 1008, GSG 20 gage (0.0396 in. or 1.01 mm) thick galvannealed steel in accordance with Specification A 653/A 653M with coating designation A 01, and 0.040 in. (1.02 mm) thick type 5052–H32 aluminum alloy in accordance with Specification B 209. Test the enameled panels of each metal as follows and record the results (see Fig. X1.1).

**Note:** This specification is intended for use on steel, galvanized steel and aluminum furniture and joiner work. Even if the product is basically all aluminum, such as for U.S. Navy furniture, it may contain parts of galvanized steel and painted steel. By daily testing all three metals all possibilities are covered.

10.1.1.1 Dry Film Thickness—See 9.2.1.
10.1.1.2 Hardness—See 9.2.2.3.
10.1.1.3 Paint Cure—See 9.2.3.4.
10.1.1.4 Adhesion—See 9.2.3.5.
10.1.1.5 Flexibility—See 9.2.3.6.
10.1.1.6 *Impact Resistance*—See 9.2.3.7. Test the remaining set of prime coated only panels in salt spray in accordance with 9.2.2.1 and 9.2.2.2, evaluate them in accordance with 9.2.2.3 and 9.2.2.4, and report results on the form shown in Fig. X1.1.

10.1.2 Maintain and retain copies of these daily tests and their results for historical documentation in accordance with 10.3. See Fig. X1.2 for a sample of a suitable record-keeping form.

10.1.3 See 10.4 for test panel retention requirements.

10.2 Perform in-process tests for color match, gloss, paint cure, and film thickness, on the finished product, for each color change or at least once each hour on large color runs.

10.2.1 Maintain and retain copies of these tests and results for historical documentation in accordance with 10.3. See Fig. X2.1 for sample of a suitable record-keeping form.

10.3 Retain process control records and paint test panel results for as long as is required by the procurement documents. If not addressed in these procurement documents, retain all process control records and paint test panel results only until the product has been accepted by the procuring agency and payment has been made to the product supplier.

10.4 Normally, test panels shall be retained for a period of one month but may be discarded sooner if inspected and test results are recorded on the appropriate test results form by a cognizant inspector.

10.5 Maintain an inspection of the final product for adequate paint coverage and proper appearance to produce a quality product. See Appendix X2.

11. **Keywords**

11.1 baking finish; baking primer; enamel; fabricated metal products; joiner work; marine; marine furniture; metal painting; ship

**APPENDIXES**

*(Nonmandatory Information)*

**X1. LAB TECHNICIAN**

X1.1 Perform tests on cleaning, pretreatment, and electrodeposition systems and maintain at proper operating ranges.

X1.2 *Paint Sample Tests:*

X1.2.1 Run (four) sample panels each of mild steel, aluminum, and galvanealed steel sheet each day as follows:

X1.2.1.1 Two of each material to be prime-coat only, and

X1.2.1.2 Two of each material to be top-coated over prime.

X1.2.2 Test top-coated panels and one set of prime-coated only panels as follows and record the results on the Lab Technician—Paint Sample Quality Assurance Tests Form (Fig. X1.1).

X1.2.2.1 Film thickness.

X1.2.2.2 Hardness.

X1.2.2.3 Paint cure.

X1.2.2.4 Adhesion.

X1.2.2.5 Flexibility.

X1.2.2.6 Impact resistance.

X1.2.3 Test the remaining set of prime-coated samples in salt spray and record the results on the Salt Spray Data Form (Fig. X1.2).
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FIG. X1.1 Lab Technician—Paint Sample Quality Assurance Tests Form
X2. FINAL PRODUCTION PRODUCT INSPECTION

X2.1 The following quality assurance checks are to be made at least once every hour on large color runs or on each color change. Record results on the Paint Shop Production Line, Quality Assurance Check List Form Fig. X2.1).

X2.1.1 Color match.
X2.1.2 Gloss.

X2.1.3 Paint cure.
X2.1.4 Dry film thickness.

X2.2 The following quality assurance checks are to be made on each item as it is removed from the paint line.

X2.2.1 Paint coverage.
X2.2.2 Appearance:

X2.2.2.1 Runs.
X2.2.2.2 Blisters.
X2.2.2.3 Bumped or dented material requiring filling.

X3. PAINT SAMPLE QUALITY ASSURANCE SALT SPRAY TESTS

X3.1 Samples—One sample panel each of mild steel, aluminum, and galvanized steel sheet that have been enameled shall be tested each production day.

X3.1.1 Panels must be checked for dry film thickness and scribed through the paint coat to expose the underlaying metal before testing.

X3.2 Testing—Test panels shall be continuously tested in accordance with Practice B 117.

X3.2.1 Panels shall be tested for 250, 500, 750, and 1000 h, with results at each interval recorded on the Salt Spray Data Form (Fig. X1.2).

X3.3 Records—Copies of Salt Spray Data Form (Fig. X1.2) showing tests results must be forwarded to Quality Assurance and the plant manager for evaluation.

X3.3.1 Quality Assurance will maintain a reference file on all daily salt spray test results. (See 10.3.)
X3.3.2 After test results have been recorded and any failures evaluated by Quality Assurance, test panels may be discarded.

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Standard Practice for
Inspection Procedure for Use of Anaerobic Thread Locking Compounds with Studs

This standard is issued under the fixed designation F 1179; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers an inspection procedure to ensure that studs installed with an anaerobic thread locking compound have achieved the necessary backout resistance.

1.2 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. General Requirements

2.1 Application of anaerobic compounds, used as a method for locking threaded fasteners, shall be in accordance with the anaerobic compound manufacturer’s recommendations.

2.2 Responsibility for Inspection—Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein.

2.3 Government Inspection System—For U.S. Navy procurements, each organization shall maintain an inspection system to ensure that all of the requirements of this practice are being met wherever anaerobic compounds are used for locking threaded fasteners.

3. Stud Installation Verification

3.1 Verification of fastener locking effectiveness of anaerobic compounds, after the manufacturer’s recommended setting period, shall be in accordance with the following:

3.1.1 Witness installation and removal through a distance of three threads beyond the locking element of a previously unused nut (annular plastic ring locking element type) on two studs in each joint bolt circle containing more than three studs.

3.1.1.1 Locate selected studs 180° apart or as close thereto as possible.

3.1.1.2 Examine only one stud in applications having three studs or less.

3.1.2 Accept the assembly if no turning motion of the studs is observed during nut installation or removal. Also, accept the assembly if a slight initial turning motion (up to ¼ turn) of the studs is observed, and no further turning motion of the studs is observed, during nut installation or removal. A small initial turning of the set stud represents a breaking or powdering of the locking compound which actually increases resistance to any further turning motion.

3.1.2.1 Do not restrain studs from turning during the test by any method other than the locking compound in the set end of the stud.

3.1.3 Reject each stud assembly if the requirements for acceptance of 3.1.2 are not met. If one assembly is rejected, all studs in that bolt circle shall be similarly checked (see 3.1.1 and 3.1.2). Remove and clean all rejected studs in accordance with the manufacturer’s recommended procedures, reinstall, and reinspect.

3.1.3.1 Reinspection shall consist of selecting two of the reinstalled studs, if four or more studs require reinstallation, or one stud if less than four studs require reinstallation, and performing procedures 3.1.1, 3.1.2, and 3.1.3.

3.1.4 If assembly is accepted after step 3.1.2, each stud in the bolt circle shall be permanently marked (scribe or electro-etched) on the exposed end with a line oriented radially in relation to the center of the bolt circle.

4. Joint Assembly Inspection

4.1 Joint assembly shall be completed and final torque applied:

4.1.1 Note the position of the orientation line (see 3.1.4) on the studs. If the orientation line position indicates that studs have not turned more than ¼ turn, accept the joint assembly.

4.1.2 If the orientation line position indicates one or more studs have turned more than ¼ turn, reject the joint, disassemble the joint, and remove and clean the studs which failed in accordance with the manufacturer’s recommended procedures, reinstall, and reinspect.

4.1.3 Reinspection of the stud shall consist of procedures 3.1.1, 3.1.2, and 3.1.3.

4.1.4 Reinspection of the joint assembly shall consist of procedures 4.1.1 and 4.1.2.

4.1.5 Repeat the removal and reinstallation procedure until the orientation line shows that studs have not turned more than ¼ turn during the final torquing.
5. Keywords

5.1 anaerobic compound; inspection; locking threaded fastener
Standard Specification for Anodes, Sacrificial Zinc Alloy

This standard is issued under the fixed designation F 1182; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (¢) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the requirements for zinc anodes in the form of slabs, plates, discs, and rods for corrosion protection (cathodic protection) of metals and alloys.

1.2 The anodes are primarily intended to reduce corrosion of surface ship and submarine hulls, steel and aluminum equipment and structures, sea chests, sonar domes, and the seawater side of condensers and other heat exchangers.

1.3 The values stated in inch-pound units are to be regarded as standard. The metric (SI) units, given in parentheses, are for information purposes only and may be approximate.

1.4 This standard does not purport to address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 Order of Precedence—In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

2.2 ASTM Standards
A 36/A36M Specification for Carbon Structural Steel
B 21 Specification for Naval Brass Rod, Bar, and Shapes
B 103 Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar
D 3951 Practice for Commercial Packaging
E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials
E 536 Test Method for Chemical Analysis of Zinc and Zinc Alloys

2.3 Military Standards:

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-1186 Cushioning, Anchoring, Bracing, Blocking, and Waterproofing; With Appropriate Test Methods

2.4 Military Specification:

MIL-P-15011 Pallets Material Handling, Wood Post Construction, 4-Way Entry

2.5 Federal Specifications:

PPP-B-601 Boxes, Wood, Cleated Plywood
PPP-B-621 Boxes, Wood, Nailed and Lock-Corner
PPP-B-636 Boxes, Shipping, Fiberboard

2.6 American National Standards Institute Standard:

ANSI/ASME B1.20.1—Pipe Threads, General Purpose (Inch)

3. Classification

3.1 The anodes shall be of the following classes and types, as specified (see 4.1.2):

3.1.1 Class 1—Cast-in cores:

3.1.1.1 Type ZHS—Zinc, hull slab, steel straps, 23 and 42-lb (10 and 19-kg) sizes.

3.1.1.2 Type ZHB—Zinc, hull slab, brass straps, 23-lb (10-kg) size.

3.1.1.3 Type ZHC—Zinc, hull slab, core strap, 23 and 42-lb (10 and 19-kg) sizes.

3.1.1.4 Type ZSS—Zinc, submarine slab, steel strap, 12 and 24-lb (5 and 11-kg) sizes.

3.1.1.5 Type ZTS—Zinc, teardrop shape, steel strap, 5-lb (2-kg) size.

3.1.1.6 Type ZEP—Zinc, heat exchanger or fair water disc, (pipe core or pipe bushing core):

Style A square slab, 9-lb (4-kg) size
Style B circular slab, various sizes
Style C semicircular slab, 23-lb (10-kg) size

3.1.1.7 Type ZBP—Zinc, bar, pipe core, 8-lb (4-kg) size.

3.1.1.8 Type ZDM—Zinc, segmented disc, machine formed interlocking core, various sizes.

3.1.2 Class 2—Plain, no cores;
3.1.2.1 Type ZRN—Zinc, rod, no core, extruded, drawn or rolled.

3.1.2.2 Type ZPN—Zinc, plate, no core, rolled.

3.2 The letter designations of types of anodes have the following meanings:

3.2.1 The first letter designates anode metal:
- Z zinc

3.2.2 The second letter designates the shape or general use:
- H hull slab
- S submarine slab
- T teardrop shape
- E heat exchanger slab
- R rod, cylindrical
- P plate
- B bar, square
- D disc, segmented

3.2.3 The third letter designates the core:
- B brass straps
- S steel straps
- C core strap
- P pipe core
- M machine formed interlocking core
- N no core

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 ASTM designation and year of issue,

4.1.2 Class and type (see 3.1),

4.1.3 Style of Type ZEP, if required (see 3.1.1.6 and Fig. 1),

4.1.4 Diameter of Type ZEP, Style B, if required (see Fig. 1),

4.1.5 For Type ZDM, whether straight or tapered thread support plug head is required (see section 5.1.4.2),

4.1.6 Diameter of Type ZDM, if required (see Fig. 2),
4.1.7 Length, width, and thickness of Type ZHS, if required (see Fig. 3 and Fig. 4),

4.1.8 Whether Type ZHC is for surface ship or submarine usage, if required (see Figs. 5-8),

4.1.9 Pipe or bolt diameter of Type ZRN, if required (see Fig. 9),

4.1.10 Thickness of Type ZPN, if required (see 9.2.1),
4.1.11 Quantity required (see 4.2),

4.1.12 Quality assurance certification, if required (see 15.1),

4.1.13 Optional requirements, if any (see S1 through S3).

4.2 The order for anodes should specify the exact number of anodes required (see 4.1.11). Acquisition of anodes by weight is not practical and is not recommended.

5. Materials and Manufacture

5.1 Materials:

5.1.1 Types ZHS, ZHC, ZSS, and ZTS anodes shall have steel strap cores in accordance with Specification A 36/A36M. The steel shall be coated with zinc, either by the hot-dip or electrodeposition method, to a minimum of 0.0005 in. (0.013 mm).

5.1.2 Type ZHB anodes shall have brass strap cores in accordance with alloy 482 of Specification B 21 or phosphor bronze straps in accordance with C51000 of Specification B 103. The brass or bronze straps shall be coated with zinc to a minimum thickness of 0.0005 in. (0.013 mm). Lack of adhesion of the zinc coating at bend or absence of zinc coating at cut edges will not be cause for rejection of fabricated anodes. Cracks in the base metal shall be cause for rejection.

5.1.2.1 The maximum copper content in the zinc, as specified in Table 1, may be increased to 0.020 % for Type ZHB anodes.

5.1.3 Types ZEP and ZBP anodes shall have core inserts made from zinc coated steel pipe or pipe couplings. The minimum thickness of the coating shall be as specified in 5.1.1.

5.1.4 Type ZDM anodes shall have machine formed interlocking cores in accordance with commercial grade mild or leaded steel. The cores shall be flash coated with zinc, tin, or aluminum before assembly within the anodes.

5.1.4.1 This core insert consists of an integral piece having a threaded male stud at one end and a tapped hole at the other.
end. Provision has been made to achieve self-locking characteristics to interlocking threaded assemblies of multiple segmented anode discs by interference fit of bottom male threads into a taper tapped hole.

5.2 Manufacture:

5.2.1 All anodes covered under this specification shall be manufactured by any process suitable to the contracting agency provided they meet the mechanical properties and other requirements of this specification.

5.2.2 For Types ZHS, ZHB, ZHC, ZSS, and ZTS anodes, open or closed molds may be used. Cores and straps shall be positioned so that they are embedded $\frac{1}{4}, +\frac{1}{8},$ or $-\frac{1}{16}$ in. (6, +3, or −2 mm) as shown on Figs. 3-5, Fig. 7, and Fig. 10 and Fig. 11, which may be measured from either surface of the anode as applicable, except Fig. 11 (bottom), which shall be embedded $\frac{3}{8}, +\frac{1}{8},$ or $-\frac{1}{16}$ in. (10, +3, or −2 mm).

5.2.2.1 Type ZHC anodes designated as shown on Fig. 6 and Fig. 8 and are intended for use with rubber washers for submarine application. The countersink for the rubber washer may be cast or machined. The anode shall be manufactured so that the countersink is centered on the core hole and the rubber washer fits snugly between the hull and anode core to prevent anode movement or vibration.

5.2.2.2 Type ZSS, ZHS, ZHB, and ZTS anodes may be mounted by welding or by fasteners. Those intended to be attached by fasteners shall indicate the requirements for mounting holes in the strap. The mounting hole shall be counterbored on the structure side of the strap.

5.2.3 The pipe core inserts for Type ZEP anodes shall conform to 5.1.3. The position of the pipe core insert shall not vary more than $\pm \frac{1}{8}$ in. (3 mm) from the center as shown on Fig. 1.

5.2.5 Metallic bonding or an interference fit of the core into Type ZDM anode (see Fig. 2) shall be required so that an axial force applied from the stud end to remove the core insert is a minimum of 750 lb (340 kg) (see 13.1.3).  

5.2.6 The machine formed core insert specified in 5.1.4 shall be manufactured in accordance with details and tolerances shown for Piece 2 on Fig. 1 and ANSI/ASME B1.20.1. 

5.2.6.1 The pieces shown on Fig. 1 shall screw together very snugly by hand tightening or by using simple hand tools such as pliers or pipe wrenches.
6. Chemical Composition

6.1 The anodes shall conform to the composition specified in Table 1. Total of elemental constituents not specified in Table 1 shall not exceed 0.10%. Metallic elements not specified in Table 1 are considered contaminants.

7. Mechanical Properties

7.1 When tested in accordance with 13.2, Types ZRN rods and ZPN plates shall not fracture or show signs of cracking.

7.2 When tested in accordance with 13.2.1, ZRN anodes shall have a minimum torsional shear strength of 12 000 psi (83 MPa).

8. Other Requirements

8.1 When tested in accordance with 13.1.1 or 13.1.2, Types ZHS, ZHB, ZHC, ZSS, ZTS, ZEP, and ZBP anodes shall obtain a sound metallurgical bond between the zinc and core for at least 30% of the total surface area of each core in contact with the anode.

8.2 During the manufacturing process, certain toxic compounds (such as zinc phosphide) may become by-products. Caution should be taken in disposal of process wastewater to ensure that the composition of the water meets with local, state, and federal regulations.


9.1 Types ZHS, ZHB, ZHC, ZTS, ZSS, ZEP, ZBP, ZDM, and ZRN anodes shall be in accordance with the dimensions shown in Figs. 1-11, inclusive.

Note 1—Anode may be cast with exposed face in the up or down position. All dimensions are in inches.

Note 2—Tolerance ± 1/8 in.

Note 3—1 in. = 25.4 mm.

Note 4—Minimum weight 21.5 lb (9.7 kg).

FIG. 5 Zinc Hull Slab (Core Strap), Type ZHC-23

Note 1—Anode may be cast with exposed face in the up or down position. All dimensions are in inches.

Note 2—Tolerance ± 1/8 in.

Note 3—1 in. = 25.4 mm.

Note 4—Minimum weight 21.5 lb (9.7 kg).

FIG. 6 Zinc Hull Slab (Core Strap), Type ZHC-23, Submarine Application

9.2 Type ZPN anode shall be 48 in. (1220 mm) in length by 24 in. (610 cm) in width.

9.2.1 The thickness shall be either 1/2 or 1 in. (13 or 25 mm) as specified (see 4.1.10).

9.3 Types ZSS-12, ZSS-24, ZHC-23, ZHC-42, ZHS-23, and ZHS-42 shall have the following minimum weight requirements:

<table>
<thead>
<tr>
<th>Anode</th>
<th>Weight, min, lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSS-12</td>
<td>11.0 (5)</td>
</tr>
<tr>
<td>ZSS-24, ZHC-23, ZHS-23</td>
<td>21.5 (10)</td>
</tr>
<tr>
<td>ZHC-42</td>
<td>39.0 (18)</td>
</tr>
<tr>
<td>ZHS-42</td>
<td>41.0 (19)</td>
</tr>
</tbody>
</table>

9.3.1 The total weight of the specified type of anode received divided by the total number of anodes of that type shall be equal to or greater than the minimum weight (11.0, 21.5, 39.0, 41.0 lb (5, 10, 18, 19 kg)) of the anode type specified. If the weight is less than the minimum weight for the type of anode specified, it shall be cause for rejection of the entire lot.
9.4 The length and width of Types ZHS, ZHB, ZHC, ZTS, ZPN, ZSS, and ZBP anodes shall not vary more than \( \frac{1}{8} \) in. (3 mm), measured at the widest surface of the tapered (for mold release) anode.

9.5 The length of Type ZRN anodes will be permitted to have a variation of \( \pm \frac{1}{32} \) in. based on nominal lengths of 3 and 6 ft (914 and 1829 mm).

9.6 The diameter or width, whichever is the larger, of Type ZEP anodes shall not vary from the specified dimension by more than \( \frac{1}{8} \) in. (3 mm).

9.7 The diameter of Type ZDM anodes shall not vary more than \( \pm 0.005 \) in. (0.13 mm) from the specified diameter.

9.8 The diameter of the ZRN anode shall not vary more than \( \pm \frac{1}{2} \) in. (1 mm) from the specified diameter.

9.9 The thickness of Types ZHS, ZHB, ZHC, ZTS, ZPN, ZSS, ZEP, and ZBP anodes shall not vary more than \( \pm \frac{1}{8} \) in. (3 mm). Thickness measurements shall be taken at random 1 in. (25 mm) from any edge of the anode by means of a suitable caliper avoiding any surface irregularities which would interfere with a representative measurement.

9.10 The thickness of Type ZDN anodes shall not vary more than \( \pm \frac{1}{64} \) in. (0.4 mm).

9.10.1 The cores of Type ZDM anodes shall be positioned axially and concentrically in the zinc disc. Eccentricity greater than 0.005 in. (0.13 mm) will not be permitted.

10. Workmanship, Finish, and Appearance

10.1 The zinc anodes shall be free of flash burrs, cracks, blow holes, pipes, and surface slag consistent with good commercial practice.

10.1.1 For anodes less than 2 in. (50 mm) thick, when measured with a straightedge placed diagonally across the opposite edges of the cast anode, the anode shall be free of shrinkage cavities exceeding \( \frac{1}{4} \) in. (6 mm) in depth. Anodes 2 in. (50 mm) thick or more shall be free of shrinkage cavities exceeding \( \frac{3}{8} \) in. (10 mm) in depth.

10.1.1.1 For Type ZPN anodes, shrinkage cavities shall be measured over a 12- by 12-in. (305- by 305-mm) area and shall not exceed the dimensions specified in 10.1.1.

10.1.2 Surface irregularities of the anode exceeding \( \frac{1}{8} \) in. (3 mm) in depth shall not be permitted on either face of slab or disc type anodes unless at least \( \frac{1}{8} \) in. (3 mm) of sound metal covers the entire strap of core area.

10.2 Types ZDM and ZRN anodes shall be smooth on their curved surfaces.

10.3 Metal core extensions from the anodes shall be smooth and free of sharp burrs. The cast-in cores shall have metallurgical bonds specified herein free of air pockets and inclusions consistent with good commercial practice.

10.4 The coatings specified in 5.1.1 shall be adherent and free from flaking. The coating shall adhere tenaciously to the surface of the base metal. When the coating is cut or pried into,
such as with a stout knife applied with considerable pressure in a manner tending to remove a portion of the coating, it shall only be possible to remove small particles of the coating by paring or whittling, and it shall not be possible to peel any portion of the coating so as to expose the steel. Lack of adhesion of the zinc coating at bends or absence of zinc coating at cut edges shall not be cause for rejection of fabricated anodes.

11. Sampling

11.1 For the purposes of sampling, a lot shall consist of all zinc anodes of the same class and type, poured or cast from one homogeneous heat or melt of a single charge of raw materials. The addition of any material to the heat or melt at any time constitutes a new lot.

11.2 Select a random sample of anodes from each lot in accordance with MIL-STD-105 at Inspection Level II for the examination specified in 14.1. In terms of defects per 100 units, the acceptable quality level (AQL) shall be 4.0 for total defects.

11.3 From each lot specified in 11.1, select two anodes at random of Types ZHS, ZHB, ZHC, ZSS, ZTS, ZEP, and ZBP and five anode discs of Type ZDM for the core bond tests specified in 13.1.1 or 13.1.2.

11.3.1 In cases in which one of the two anodes specified in 13.1.1 or 13.1.2 fails to pass the bond test, select four additional anodes for retest at the request of the manufacturer.

11.4 Select at random from the lot at least five each of both Type ZRN and ZPN anodes for the sampling for the physical testing described in 13.2.

11.5 The sampling for the chemical analysis described in 13.3 shall consist of anodes being selected at random in...
accordance with 11.3, except that sufficient number of Type ZDM anodes shall be selected to comply with 12.1.5.

11.6 Discard sample anodes, except the remaining lengths of Type ZRN anodes, and do not include them in the delivery of material after the core bond tests specified in 13.1.1 and 13.1.2 are performed. Perform sampling for chemical analysis specified in 11.5 before discarding the anodes.

12. Specimen Preparation

12.1 From each anode selected for chemical analysis in accordance with 11.5, take one 2-oz (0.06-kg) sample by drilling or machining the material at the locations specified in 12.1.1-12.1.6, inclusive. The drilling or machining shall be done by the contractor. The drill or tool bit shall not penetrate into the core material of the cored type anodes. The drilled or machined anodes may be included in the delivery of the material, except Type ZDM anode, which shall be discarded.

12.1.1 Drill or machine Types ZHS and ZHB anodes at locations about 2 to 5 in. (50 to 127 mm) from the short edge as appropriate to keep away from the encased core.

12.1.2 Drill or machine Types ZSS, ZHC, and ZTS anodes at points not greater than 1/2 in. (13 mm) from the long edge.

12.1.3 Drill Types ZEP and ZBP anodes at points midway between the outer edge of the core and the edge of the anode.

12.1.4 Drill Types ZRN and ZPN and have two 1-lb (0.45-kg) minimum sections cut from ends of a nominal length.

12.1.5 Type ZDM anodes shall have a sufficient number of discs machined or drilled at the outer surface to make two 4-oz (0.11-kg) quantities and shall be machined or drilled at the outer surface to a depth not exceeding 1/4 in. (6 mm).

12.1.6 Take one 2-oz (0.06-kg) sample for each anode specified in 12.1 at the surface in contact with mold wall by drilling or machining to a maximum of 1/4 in. (6 mm). Take the sample for Types ZPN or ZRN by drilling completely through both principal surfaces or through the diameter of the anode as applicable. Collect the samples in individual clean containers and properly label as to lot, melt, and sample numbers. Sample chips may be taken from anodes which have passed the applicable bond tests. Samples shall be clean, free from dirt, oil, grit, and foreign matter. Test the samples at a laboratory satisfactory to the contracting agency.

12.2 The drilling of samples for chemical analysis should be made with a special nonferrous drill in a clean location (used only for that purpose). Keep the drilling bits clean of dirt, grit, and other foreign matter; keep them properly sharpened; and use them only for sampling purposes. After each use, immerse the drilling bit in a degreasing solvent and wipe dry with a clean rag. Store the drilling bits, when not in use, in an
inhibited lubricating oil. Keep this oil in a covered glass container provided with an air vent. Wipe the drilling bits dry with a clean rag prior to use. Take the samples with a dry drill. If automatic power drilling is available, a solid tungsten carbide drill bit about ½ in. (13 mm) in diameter is suitable. Where a hand-held power drill is used, the drill bit should be
about ¼ in. (6 mm) in diameter. A smaller drill bit may be used where the size of the anode does not permit using the specified diameters. The drills may be used at high speeds and feeds.

12.3 Make the chips for chemical analysis with a special nonferrous tool in a place which has been cleaned for that specific purpose. Instructions specified in 12.2 apply to the use and care of this tool.

12.4 Use a strong magnet to remove any iron contamination picked up during the preparation of the chips. Wash the chips in an iron-free degreasing solvent prior to the chemical analysis.

13. Test Methods

13.1 Perform one of the following core bonding tests on Types ZHS, ZHB, ZHC, ZSS, ZTS, ZEP, and ZBP anodes.

13.1.1 Core bonding test—Cut each anode selected to represent the lot along the axis of each strap or core, and ground the cut surface reasonably smooth. Polish these surfaces with a 240-mesh emery abrasive until the zinc-strap interface is distinctly visible. Examine this interface carefully at approximately 10 times magnification. The metallurgical bond between the zinc and the strap shall be continuous for at least 30 % of the surface in contact with the anode. Zinc anodes may have a bead or buttress projecting from the anode edge along the strap not exceeding ¼ in. (6 mm). Less bond between the core and the zinc than specified herein shall be cause for rejection of the entire lot.

13.1.2 Alternate Core Bonding Test—Using any suitable method, tear the cores from each anode selected to represent the lot. The use of a sledge hammer to break the zinc away from the cores has been found to be satisfactory. Establish the area showing bond by visual inspection of the portion of the cores which were contained within the anode. Metallurgical bond between the zinc and the core shall be continuous for at least 30 % of the total surface area of each core in contact with the zinc of the anode. For the purpose of determining the surface area of the encased core in the anode, marks shall be scribed on the strap around the periphery of each anode at locations where the straps protrude from the anode. The total area of the strap shall be computed between the scribe marks. The surfaces shall have a smooth grey matte finish where bonding has been adequate and either a shiny metallic or rough, dark, or discolored finish where bonding has been inadequate. Examine both core and zinc mating surfaces. Less bond between core and zinc than that specified herein shall be cause for rejection of the entire lot.

13.1.3 A steady load of 750 lb (340 kg) from a hand operated pen press applied axially shall be required to remove the core from Type ZDM anode.

13.2 Types ZRN and ZPN anodes, selected in accordance with 11.4, shall be bent 45° around a mandrel of three times the diameter of the ZRN type anode and three times the thickness of the ZPN plate. Bend the anodes in accordance with procedures specified in Test Method E 290. After bending, inspect the convex surface of the specimens for cracking by visual examination. Any evidence of cracking shall represent failure of the test and shall be cause for rejection of the entire lot.

13.2.1 Subject the ZRN anodes specified in 13.2 to torsional shear at a rate of ten to twelve revolutions per hour using a torsional shear apparatus. Failure of the anode to withstand a torsional shear of 12,000 psi (83 MPa) shall be cause for rejection of the lot.

13.3 Analyze the chips selected in accordance with 11.5 to determine conformance with 6.1. If any sample does not conform to the chemical composition specified in Table 1, it shall be cause for rejection of the lot represented by the sample.

13.3.1 Determine the aluminum, cadmium, copper, iron, and lead content of zinc in accordance with the appropriate methods in Test Method E 536 using the atomic absorption spectrophotometer.

13.3.2 A spectrochemical analysis shall be in accordance with any applicable ASTM standard method and accepted by the purchaser.

14. Inspection

14.1 Each anode selected in accordance with 11.2 shall be visually examined for workmanship and dimensions. Where the number of anodes that do not conform to the requirements of Sections 7, 9, 10, and 16 is equal to or greater than the rejection number specified in 11.2 (AQL = 4.0), it shall be cause for rejection of the entire lot.

15. Certification

15.1 When specified in the contract or purchase order (see 4.1.12), a manufacturer’s or supplier’s certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the contract or purchase order, a report of the test results shall be furnished.

16. Product Marking

16.1 The zinc anodes, Types ZHS, ZHB, ZHC, ZSS, and ZBP, shall have the words “DO NOT PAINT” die-stamped or cast on the exposed face of the anodes (see Fig. 3, Fig. 4, Fig. 7, Fig. 11, and Fig. 12). These words are not required on Types ZEP, ZPN, ZDM, ZTS, and ZRN zinc anodes.

16.1.1 One end of each cast-in strap of each Type ZHB anode shall be painted red so that the installing activity can distinguish it from Type ZHS anodes. One coat of red paint shall be applied between the joggled bevel of the strap and zinc anode. The coating shall be approximately ¼ in. (13 mm) wide and shall extend across one side of each strap so as to be readily visible when the anode is installed. The foot of the strap shall not be painted.

16.2 All anodes shall be cast, die-stamped, or scribed with the following: manufacturer’s symbol, unique non-recurring heat number, and numbers and letters corresponding to this ASTM specification (including revision designation).

17. Packaging

17.1 Unless otherwise specified (see 4.1.13), packaging shall conform to manufacturer’s normal commercial practice, and in such a manner that will ensure acceptance by common carrier and afford protection against physical and mechanical
damage during shipment. Shipping containers shall conform to carrier regulations as applicable to the mode of transportation.

18. Keywords
18.1 anodes; disc anodes; plate anodes; rod anodes; sacrificial anodes; slab anodes; zinc alloy anodes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply for government contracts or when specified by the purchaser in the contract or purchase order (see 4.1.13).

S1. Referenced Documents
S1.1 The following documents are applicable only when one or more of the requirements of S2 are specified in the contract or purchase order (see 4.1.13): Practice D 3951; MIL-P-15011; MIL-STD-129; MIL-STD-1186; and Fed. Specs. PPP-B-601, PPP-B-621, and PPP-B-636.

S2. Packaging and Package Marking
S2.1 Preservation shall be Level A, C, or commercial, as specified (see 4.1.13).
S2.1.1 Level A—Type ZEP, Styles A and B (2- to 6-in. (51-to 152-mm) diameter, inclusive) and Type ZDM anodes shall be packaged in quantities specified in Table S1.1, unless otherwise specified (see 4.1.13), and snugly fitted into fiberboard boxes in accordance with Federal Specification PPP-B-636, class water resistant. ZEP anodes shall be immobilized within the boxes with solid fiberboard or other suitable separators so that cast-in cores cannot be loosened by impact or heavy loading. The gross weight of the boxes shall not exceed the weight limitations of the fiber box specifications.
S2.1.2 Level C—The zinc anodes shall be preserved as specified for Level A, except that nonweather resistant domestic grade fiberboard boxes may be used.
S2.1.3 Commercial—Anodes shall be preserved in accordance with Practice D 3951.
S2.2 Packing shall be Level A, B, or commercial, as specified (see 4.1.13).
S2.2.1 Level A—Anodes, segregated for type, size, and heat, shall be packed in accordance with S2.2.1.1 through S2.2.1.6.
S2.2.1.1 Types ZHS, ZHB, ZHC, ZTS, ZPN, ZSS, ZBP, and ZEP (Style B in sizes 9- and 11-in. (229- and 279-mm) diameter and Style C) anodes shall be packed in unit pallet loads or in boxes in accordance with S2.2.1.2 and S2.2.1.3.
S2.2.1.2 Pallets shall be in accordance with MIL-P-15011. The anodes shall be secured to the pallet with tension tied, coated or galvanized, steel strapping applied lengthwise and girth-wise. Minimum size of the strapping shall be 0.075 by 0.035 in. (20 by 10 mm). The gross weight of the pallet load shall not exceed 3000 lb (1362 kg).
S2.2.1.3 The boxes shall be in accordance with Federal Specifications PPP-B-601 (overseas type) or PPP-B-621, Class 2. The gross weight of the box shall not exceed approximately 500 lb (227 kg). Box closure and strapping shall be in accordance with the applicable box specification or appendix thereto. The boxes shall be modified by the addition of skids, for gross weights exceeding 200 lb (91 kg), in accordance with the applicable box specification.
S2.2.1.4 Types ZEP, Style A and B in sizes 2- to 6-in. (51-to 152-mm) diameter inclusive, and ZDM anodes packaged as specified in S2.1.1, shall be packed and snugly fitted into nailed wood or wood-cleated plywood boxes in accordance with Federal Specifications PPP-B-621, Class 2, or PPP-B-601 (overseas type), respectively. The gross weight of shipping containers shall not exceed approximately 200 lb (91 kg).
S2.2.1.5 Type ZRN anodes shall be packed as specified in S2.2.1.3.
S2.2.1.6 The anodes shall be cushioned, blocked, and braced in accordance with MIL-STD-1186.
S2.2.2 Level B—Anodes, segregated for type, size, and heat, shall be packed in accordance with S2.2.2.1 through S2.2.2.6.
S2.2.2.1 Types ZHS, ZHB, ZHC, ZTS, ZPN, ZSS, ZBP, and ZEP (Style B in sizes 9- and 11-in. (229- and 279-mm) diameter and Style C) anodes shall be packed in unit pallet loads or in boxes in accordance with the following:
S2.2.2.2 Pallets shall be as specified in S2.2.1.2.
S2.2.2.3 The boxes shall be in accordance with Federal Specifications PPP-B-621, Class 1, or PPP-B-601 (domestic type). The gross weight of the box shall not exceed approximately 500 lb (227 kg). Box closure shall be in accordance
with the applicable box specification or appendix thereto. The boxes shall be modified by the addition of skids, for gross weights exceeding 200 lb (91 kg), in accordance with the applicable box specification.

S2.2.2.4 Types ZEP, Style A and Style B in sizes 2- to 6-in. (51- to 152-mm) diameter inclusive, and ZDM anodes, packaged as specified in S2.1.1, shall be packed and snugly fitted into nailed wood and wood-cleated plywood boxes in conformance with Federal Specifications PPP-B-621, Class 1, or PPP-B-601 (domestic type), respectively. The gross weight of shipping containers shall not exceed approximately 200 lb (91 kg).

S2.2.2.5 Type ZRN anodes shall be packed in accordance with S2.2.1.5, except wood or wood-cleated containers shall be of the domestic type and for Type 3 load in accordance with Federal Specification PPP-B-601.

S2.2.2.6 The anodes shall be cushioned, blocked, and braced so as to prevent damage during shipment.

S2.2.3 Commercial—Zinc anodes that require overpacking for shipment shall be packed in accordance with Practice D 3951.

S3. Inspection

S3.1 The packaging, packing, and package marking of the anodes shall be inspected to verify compliance with the requirements of Section S2.

S3.2 The contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.
Standard Specification for Sliding Watertight Door Assemblies¹

This standard is issued under the fixed designation F 1196; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, manufacture, and testing of sliding watertight door assemblies intended to ensure the watertight integrity of personnel access openings in watertight bulkheads.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
- A 36/A 36M Specification for Carbon Structural Steel²
- F 1197 Specification for Sliding Watertight Door Control Systems³

2.2 Military Specification:
- MIL-S-901 Shock Test, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for⁴

2.3 American Bureau of Shipping:
- Rules for Building and Classing Steel Vessels⁵

2.4 Code of Federal Regulations:⁶
- Title 46, Part 159.010, Independent Laboratory: Acceptance, Listing and Termination
- Title 46, Part 163.001, Doors, Watertight, Sliding (and Door Controls), for Merchant Vessels (through the 1991 edition)

2.5 International Maritime Organization (IMO):
- International Code for the Application of Fire Test Procedures (FTP)⁷

3. Terminology

3.1 Definitions:

3.1.1 door assembly—a door panel and its associated panel stiffening.

3.1.2 frame assembly—a rigid frame designed to be attached to a watertight bulkhead. The guide tracks necessary to ensure proper door and frame alignment are also included as part of the frame assembly.

3.1.3 horizontal sliding watertight door—a sliding watertight door that opens and closes with a horizontal movement.

3.1.4 opening hand—the direction in which a horizontal sliding watertight door opens. A left-hand opening door opens to the left when viewed from the side of the bulkhead on which the door assembly is located. A right-hand opening door opens to the right when viewed from the side of the bulkhead on which the door assembly is located.

3.1.5 pressure head—the pressure which a sliding watertight door assembly is designed to withstand. For a door located below the bulkhead deck, it is equivalent to the pressure exerted by a column of water the height of which is equal to the vertical distance from the bulkhead deck to the door sill in its installed location. For a door located above the bulkhead deck, it is equivalent to the pressure exerted by the maximum head of water for its location, as determined in the damage stability calculations.

3.1.6 sliding watertight door assembly—a steel door assembly and a steel frame assembly fitted with a replaceable interface between the two that ensures watertightness between door and frame at the design pressure head.

3.1.7 vertical sliding watertight door—a sliding watertight door that opens and closes with a vertical movement.

4. Classification

4.1 Sliding watertight doors consist of four types:

4.1.1 Type IA—Horizontal doors that conform to the sizes specified in Table 1 as illustrated in Fig. 1.

4.1.2 Type IB—Vertical doors that conform to the sizes specified in Table 2 as illustrated in Fig. 2.

4.1.3 Type IIA—Horizontal doors that conform generally to the requirements of this specification, but that necessitate special requirements as indicated in Section 5.

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¹ This specification is under the jurisdiction of Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.


⁴ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

⁵ Available from American Bureau of Shipping, ABS Plaza, 16855 Northchase Dr., Houston, TX 77060.


⁷ Available from the International Maritime Organization, 4 Albert Embankment, London, SE1 7SR UK.
4.1.4 Type IIB—Vertical doors that conform generally to the requirements of this specification, but that necessitate special requirements as indicated in Section 5.

4.2 Watertight doors consist of three classes:

NOTE 1—These classifications are in agreement with those defined and accepted by the International Convention for the Safety of Life at Sea (SOLAS), regulatory bodies, and classification societies.

4.2.1 Class 1—Doors that are hinged and dogged. This specification is not applicable to this class of door.

4.2.2 Class 2—Sliding doors that are operable both locally and remotely by hand gear.

4.2.3 Class 3—Sliding doors that are operable both locally and remotely by hand and by power.

5. Ordering Information

5.1 The following shall be specified when ordering:

5.1.1 Quantity,
5.1.2 Type,
5.1.3 Class,
5.1.4 Size,
5.1.5 Opening hand,
5.1.6 Door and frame material,
5.1.7 Pressure head (if other than standard),
5.1.8 Supplementary requirements (if any),
5.1.9 Additional requirements as contracted by the manufacturer and purchaser, and
5.1.10 ASTM specification designation.

6. Design

6.1 Sliding watertight door assemblies shall be designed to maintain watertightness within the limits set forth in this specification. Doors shall be designed to open and close within the limitations specified in Specification F 1197.

6.2 Assemblies shall be of substantial and rigid construction to ensure that doors can be closed under a static head equivalent to a water height of at least 1 m above the sill on the centerline of the door.

6.3 There shall be a replaceable interface between the door and frame assemblies, such as a brass rubbing strip or resilient gasket, to ensure watertightness between door and frame at the design pressure head.

6.3.1 The replaceable interface may be incorporated into the door assembly, the frame assembly, or both.

6.3.2 Assemblies shall be designed and constructed so as to be capable of preventing the passage of smoke and flame to the end of the 1-h standard fire test described by IMO FTP.
specified by the purchaser, assemblies shall also be insulated to prevent the transfer of heat to at least the same degree as the adjacent bulkhead. A fire test is not required if the assembly design incorporates details that have been demonstrated such as by a fire test on a similar door with smaller dimensions, to prevent the passage of smoke and flame. Also, a separate pressure test to determine continued watertightness after the standard fire test is not required.

6.3.3 Assemblies shall be designed in such a manner that the replaceable interface will be protected from damage when the door is in the open position.

6.4 Sliding watertight door assemblies shall be designed to provide sufficient allowance or means of adjustment to maintain the original watertight integrity as the watertight joint wears through normal usage.

6.5 Means shall be provided for lubrication of all parts necessary for satisfactory operation.

6.6 Sliding watertight door assemblies shall have a maximum horizontal opening of 48 in. (122 cm).

6.7 Door Assemblies—Type I (standard) doors are designed for a pressure head of 20 ft (6 m) of water. Type II (nonstandard) doors shall be designed for the pressure head as specified in 3.1.5 and 5.1.7, but not less than 20 ft (6 m) for doors installed below the bulkhead deck.

6.7.1 The door panel and panel stiffener assembly shall be designed based on 40% of the yield strength of the material used to construct the panel and its stiffeners (see 7.1).

6.7.2 The door panel and stiffener assembly shall have a maximum deflection of span/240.

6.7.3 Retaining grooves or aligning strips shall be provided at the tops and bottoms of horizontal assemblies and at the sides of vertical assemblies to maintain doors in proper alignment when they are not in the closed position.

6.8 Frame Assemblies—The door frame shall be continuous on all four sides. The door frame shall be of sufficient rigidity to maintain a watertight seal under the applicable operating conditions and the design head as specified in 6.7.

6.8.1 If the door frame is to be welded to the bulkhead on a reinforcing member, which acts as a secondary frame and which is continuous around the door opening, the I of that member may be included to obtain the required frame I value. (See also the Appendix X1.)

6.8.2 The frame extension for sliding watertight doors shall be made in one continuous piece, or suitable construction shall be used to ensure proper alignment.

6.8.3 Horizontal doors shall be supported by lubricated rollers to maintain alignment and minimize friction.

6.8.4 The bottom of the frame assembly shall be designed so the door will not be prevented from closing properly by lodgements of dirt or debris.

6.8.5 A sill plate of 3/16-in. (5-mm) minimum thickness may be used to cover the bottom trackway provided it is designed to retract automatically when the door closes. Sill plate hinges shall be designed and located to prevent clogging with dirt.

6.9 Actuating Component Attachments—Assemblies shall be fitted with the necessary attachments for actuating components and controls.

6.9.1 Door control systems shall comply with the requirements of Specification F 1197.

7. Materials and Manufacture

7.1 Materials:

7.1.1 The door panel, panel stiffness, door frame, tracks, and all attachments affecting watertight integrity shall be made of a material accepted in the Rules for Building and Classing Steel Vessels of the American Bureau of Shipping (ABS Rules) for use in the fabrication of watertight subdivision bulkheads, for example, Specification A 36/A 36M steel. Special consideration shall be given to the choice of materials for components exposed to corrosive environments such as on assemblies located in engine rooms and cargo holds.

7.1.2 All fasteners shall be brass or stainless steel suitable for the purpose intended.

7.2 Manufacture:

7.2.1 All welding of the door frame shall be continuous. Door panel stiffeners may be attached by intermittent welding. All welding shall be in accordance with the requirements of Part I, Section 30 of the ABS Rules.

7.2.2 All load-bearing main structural components of the door and frame shall have a minimum thickness of ¼ in. (7 mm).

7.2.3 The contact surfaces of the door and frame shall be finished as necessary to provide a plane surface and a joint that meets the requirements of this specification. Cast doors and frames, and doors and frames fabricated by welding, shall be thermally stress relieved before final machine work is performed.

8. Workmanship, Finish, and Appearance

8.1 All sharp and ragged edges shall be ground flush and removed.

8.2 Door, frame, and guide rail assemblies shall be abrasive blasted to “near white” metal in accordance with good commercial practice and coated with a nonhazardous primer.

9. Inspection and Testing of Doors

9.1 Shop Tests and Inspections (see also the Supplementary Requirements):

9.1.1 Visual Examination—Each completed door and frame shall be examined for quality workmanship and to assure conformance to design plans and this specification.

9.1.2 Hydrostatic Test—Each completed sliding watertight door assembly shall be subjected to a hydrostatic shop test to verify its strength, rigidity, workmanship, and watertightness.

9.1.2.1 Hydrostatic Test Setup—The door frame shall be mounted in either a vertical or horizontally flat position on a reinforced test plate or slab. Means shall be provided to vent air from the enclosure formed by the door, frame, and plate and to supply water, at the required test pressure, to this enclosure. Means shall also be provided for catching and measuring the amount of water that leaks between sealing surfaces of the door panel and frame. Except in the case of double-seated doors, it will only be necessary to apply pressure to that side of the door which will tend to separate the sealing surfaces.

9.1.2.2 Hydrostatic Test Procedure—The door shall be closed by operating equipment that restricts the amount of
closing force to that available from the operating gear to be used in the shipboard installation. The enclosure shall then be completely filled with water, the air shall be vented, and the test pressure shall be applied and held for at least 10 min during which time the leakage rate shall be determined. The test pressure shall not be less than that specified in 6.7 and 6.8. The measured leakage rate,  \( A \), shall not exceed that given by the following formula:

\[
A \text{ (gal/h)} = \frac{\left(P + 15\right)}{30} \times \left(\frac{h^3}{1600 \text{ or } p^3}{130}\right)
\]

where:
- \( P \) = perimeter of door opening, ft;
- \( h \) = test head, ft; and
- \( p \) = pressure, lb/in.\(^2\).

10. Certification

10.1 The manufacturer shall furnish to the purchaser written certification for each sliding watertight door assembly. The certification shall specify that the assembly has been manufactured, inspected, and tested in accordance with this specification and that it has been found to meet the requirements contained herein (see also S3.1.3).

11. Nameplate

11.1 Watertight Door Nameplate—A substantial corrosion-resistant nameplate shall be permanently attached to each watertight door on which is legibly stamped the name of the manufacturer, manufacturer’s serial number, ASTM specification designation, pressure head, the fire endurance rating in accordance with IMO FTP, and the date (see also Supplemental Requirement S4).

12. Packaging and Package Marking

12.1 Sliding watertight door assemblies shall be crated or attached to a pallet in a manner acceptable for shipment by a common carrier. The door and door frame assemblies shall be shipped as one unit.

12.2 Machined surfaces shall be coated with a preservative before shipment.

12.3 Operating controls should be packaged with the door for shipment. See Specification F 1197 for packaging requirements for controls.

12.4 Marking—Shipments shall be marked with the customer and purchase order, ASTM specification designation, classification, size, and other pertinent data as required by the applicable purchase order.

13. Keywords

13.1 marine; ship; shipboard equipment; watertight doors

**SUPPLEMENTARY REQUIREMENTS**

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Installation Tests and Inspection

S1.1 Visual Inspection—The sealing surfaces of sliding watertight door assemblies shall be examined insofar as possible without dismantling the door. Surface blemishes shall be corrected by stoning or draw-filing.

S1.2 Tests for Tightness:

S1.2.1 Feeler Gage Test—Sliding watertight door assemblies that have a machined interface between the door and frame shall be sufficiently tight to reject the insertion of a 0.003-in. (0.076-mm) feeler gage, or its clear passage through and between the sealing surfaces, at any point around the sealing perimeter.

S1.2.2 Hose Test—Sliding watertight door assemblies that incorporate a nonmetallic gasket between the door and frame shall be hose tested after installation. Water at a hose pressure of 50 psi (345 kPa) shall be supplied through a smooth bore nozzle with an orifice opening of 3/8 in. (15.9 mm), attached to a 1 1/2-in. (38-mm) hose. The nozzle shall be held at a distance of no greater than 5 ft (1.5 m) from the door. The stream shall be directed at all points of the door/frame interface. No leakage shall occur.

S2. Shock Testing

S2.1 Shock testing shall be conducted in accordance with MIL-S-901.

S2.2 The purchaser shall specify the required door positions during the test (for example, open, closed, or both).

S3. Prototype Verification

S3.1 The following additional requirements must be met for a prototype of each sliding watertight door assembly to be installed in subdivision bulkheads aboard vessels inspected and certified by the U.S. Coast Guard. Doors manufactured in accordance with 46 CFR Part 163.001 (through the 1991 edition) need only meet the additional marking requirements of S4.

S3.1.1 Plans and calculations for each assembly design shall be certified by a registered professional engineer as complying with the design requirements of Section 6 of this specification. Certified plans and calculations shall be permanently maintained by the manufacturer and made available to the Coast Guard and purchaser upon request.
S3.1.2 The inspection and testing required by Section 9 of this standard specification shall be conducted on a prototype of each sliding watertight door assembly design and witnessed by any classification society or by an organization that meets the requirements of 46 CFR Part 159.010. Test results shall be permanently maintained by the manufacturer and made available to the Coast Guard and purchaser upon request.

S3.1.3 The certification required by Section 10 of this specification shall also include the name and registration number of the professional engineer who certified the plans and calculations in accordance with S3.1.1 and the date that such certification was made. It shall also include the name of the independent third-party employee who witnessed the tests and conducted the inspections required by S3.1.2, the testing organization for whom the inspector works, and the date on which the tests were successfully completed.

S4. Additional Marking

S4.1 For doors intended for installation aboard vessels inspected and certificated by the U.S. Coast Guard, including doors manufactured in accordance with plans previously approved under 46 CFR Part 163.001, the watertight door nameplate required by 11.1 of this specification shall include the following additional phrase: “Suitable for installation in subdivision bulkheads abroad vessels inspected and certificated by the U.S. Coast Guard.”

APPENDIX
(Nonmandatory Information)

X1. INSTALLATION

X1.1 Bulkhead Reinforcement—Before a sliding watertight door assembly is installed in a vessel, the bulkhead in the vicinity of the door opening shall be stiffened in accordance with plans previously submitted by the shipyard or naval architect and approved by the U.S. Coast Guard and ABS. Such bulkhead stiffeners, or deck reinforcement where flush deck door openings are desired, shall not be less than 6 in. (152 mm) nor more than 12 in. (305 mm) from the door frame in order that an unstiffened diaphragm of bulkhead plating 6 to 12 in. (152 to 305 mm) wide is provided completely around the door frame. Where such limits cannot be maintained, the applicable classification society and regulatory body should be contacted for specific approval of the particular installation. In determining the scantlings of these bulkhead stiffeners, the door frame should not be considered as contributing to the strength of the bulkhead. Provision shall also be made to support the thrust bearings and other equipment that may be mounted on the bulkhead or deck adequately.

X1.2 Sliding watertight door frames may be either bolted or welded watertight to the bulkhead.

X1.2.1 If bolted, a suitable thin heat- and fire-resistant gasket or suitable compound shall be used between the bulkhead and the frame for watertightness. The bulkhead plating shall be worked to a plane surface in way of the frame when mounting.

X1.2.2 If welded, precaution shall be exercised in the welding process so that the door frame is not distorted.
Standard Specification for Sliding Watertight Door Control Systems

This standard is issued under the fixed designation F 1197; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers the design, manufacture, and testing of controls and operating mechanisms for use with sliding watertight doors meeting the requirements of Specification F 1196.
1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

2. Referenced Documents
2.1 ASTM Standards:
A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes
F 1196 Specification for Sliding Watertight Door Assemblies
2.2 Institute of Electrical and Electronic Engineers Standards:
IEEE 45 Recommended Practice for Electrical Installations on Shipboard
IEEE 100 IEEE Standard Dictionary of Electrical and Electronic Terms
2.3 Society of Automotive Engineers Standards:
J524 Seamless Low Carbon Steel Tubing Annealed for Bending and Flaring
J525 Welded and Cold Drawn Low Carbon Steel Tubing Annealed for Bending and Flaring
2.4 Military Specification:
MIL-S-901 Shock Test, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for
2.5 American Society of Mechanical Engineers:
Section VIII, Division 1, ASME Boiler and Pressure Vessel Code, Pressure Vessels
2.6 National Electrical Manufacturers’ Association:
Publication Number IS1.1 Enclosures for Industrial Controls and Systems

3. Terminology
3.1 Definitions:
3.1.1 control station—a location from which a sliding watertight door may be closed.
3.1.2 door control—the device that must be physically activated by the operator to initiate the opening or closing of a sliding watertight door.
3.1.3 door control system—the system of components necessary to operate a sliding watertight door, consisting of the door control, operating mechanism, and interconnecting components.
3.1.4 electrical control voltage—the voltage applied to the door controls, indicators, and alarms.
3.1.5 electrical system voltage—the voltage generated by the electrical power sources at which the operating mechanism will operate.
3.1.6 interconnecting components—those components between the door control and the operating mechanism necessary to cause the operating mechanism to move a sliding watertight door as directed by the door control or between the door and the remote indicator. Interconnecting components form a mechanical, hydraulic, or electrical system between the control station and the door and between the door and the remote indicator.
3.1.7 local control station—a location adjacent to a sliding watertight door from which the door may be opened or closed.
3.1.8 manual control—a door control that requires the operator to apply a continuous cyclic force, for example, the turning of a handwheel or operating of a pump handle, to cause the operating mechanism to function.
3.1.9 operating mechanism—the device, be it mechanical, electric, or hydraulic, that directly causes a physical force to be placed upon a sliding watertight door to cause its movement.
3.1.10 power control—a door control that requires the operator to exert a minimal physical force, for example, pushing of a

4 Available from Institute of Electrical and Electronics Engineers, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855–1331.
5 Available from Society of Automotive Engineers, Inc., 400 Commonwealth Dr., Warrendale, PA 15096–0001.
6 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.
8 Available from National Electrical Manufacturers’ Association, 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
button, flipping of a switch, or holding of a lever, to cause the operating mechanism to function.

3.1.10 remote control station—a location from which a door or doors can be remotely closed.

3.1.11 remote indicator—the device, mechanical or electric, located at a remote control station that indicates whether a door is open, closed, or at an intermediate position.

4. Classification

4.1 Sliding watertight door control systems are of the following types:

4.1.1 Manual—a door control system that requires the operator to apply a continuous cyclic force to the door controller to cause the operating mechanism to function. Manual control systems consist of the following types:

4.1.1.1 Mechanical—An operating system, such as that consisting of a handwheel, shafting, gears, universal joints, and a rack and pinion assembly.

4.1.1.2 Hydraulic—A system consisting of a hand pump, fluid power cylinder, and interconnecting pipe, tubing, valves, and fittings.

4.1.2 Power—A door control system that requires only that the operator exert a minimal physical force to cause the operating mechanism to function. Power control systems consist of the following types:

4.1.2.1 Electric—A system consisting of a pushbutton, switch, or lever that activates, through an electric circuit, an electric motor that drives a rack and pinion operating mechanism that applies the necessary force to open and close the door.

4.1.2.2 Hydraulic—A system consisting of a lever-operated control valve, hydraulic accumulator, and interconnected pipe, tubing, valves, and fittings that actuates a fluid power cylinder operating mechanism that applies the necessary force to open and close the door.

4.1.2.3 Electrohydraulic—A system consisting of a combination of electric and hydraulic components, whereby a pushbutton, switch, or lever, through an electric circuit, activates an electric motor that drives a hydraulic pump that supplies hydraulic fluid under pressure to an operating mechanism consisting of a fluid power cylinder that applies the necessary force to open and close the door.

5. Ordering Information

5.1 Specify the following information when ordering:

5.1.1 Quantity,

5.1.2 Door type,

5.1.3 Door class,

5.1.4 Opening hand,

5.1.5 Door size,

5.1.6 Design pressure head of door,

5.1.7 Type of control system,

5.1.8 Electrical system voltage,

5.1.9 Electrical control voltage,

5.1.10 Distance from the door to remote control stations,

5.1.11 Remote control panel requirements (if applicable),

5.1.12 Supplementary requirements (if any),

5.1.13 Additional requirements as contracted by the manufacturer and purchaser, and

5.1.14 ASTM specification designation.

6. Materials and Manufacture

6.1 Cast iron components shall not be used unless shock tested and approved in accordance with MIL-S-901.

7. Design of Manual Operating Controls

7.1 All sliding watertight doors shall be provided with a means of local and remote manual operation.

7.2 The maximum force required to operate each manual control shall be 25 lbs (11 kg), except that a maximum force of 50 lbs (23 kg) is acceptable during wedging if applicable.

7.2.1 Hand pumps may operate with an all around crank motion or a reciprocating motion.

7.2.2 Handwheels shall be at least 18 in. (457 mm) in diameter.

7.3 Manual controls shall remain stationary when the door is operated by other means.

7.4 Local Manual Controls:

7.4.1 Local manual controls shall be capable of opening and closing each door from both sides of the bulkhead.

7.4.2 Local manual controls shall be located within 10 ft (3 m) of, and in visual contact with, the door.

7.4.3 Local manual controls shall always operate, even in the event of rupture of hydraulic lines more than 10 ft (3 m) from the door.

7.5 Remote Manual Controls:

7.5.1 A remote manual control shall be provided above the bulkhead deck to close each door remotely.

7.5.1.1 It shall not be possible to open a door remotely.

7.5.2 A remote indicator, operable under all conditions, shall be located at the remote manual control station to indicate whether the door is open or closed.

8. Design of Power Operating Controls

8.1 Each Class 3 door, as defined in Specification F 1196, shall be provided with local power controls for opening and closing the door and remote power controls for closing the door. Door control systems intended for installation aboard Coast Guard inspected and certificated vessels shall comply with Supplementary Requirements S1 through S4 in addition to the following.

8.1.1 Local Power Controls:

8.1.1.1 Local power controls shall be so located that they may be held in the open position by a person passing through the doorway.

8.1.1.2 The controls shall be at least 48 in. (122 cm) above the deck.

8.1.1.3 The direction of movement of handles used to open and close the door shall be in the direction of the door movement.

8.1.2 Remote Power Controls:

8.1.2.1 Remote power controls shall be located on a central control station located on the navigating bridge.

8.1.2.2 The central control station shall have a “master mode” switch with two modes of control. (I) The “local control” mode shall allow any door to be locally opened and locally closed after use without automatic closure of the door.
8.1.2.3 A diagram shall be provided on the central control station showing the location of each door, with visual indicators to show whether each door is open or closed. A red light shall indicate that a door is fully open, and a green light shall indicate that it is closed. A flashing red light shall indicate that a door is in an intermediate position.

8.1.2.4 The central control station shall be fitted with a test button to verify that all lights at the station are in proper working order.

8.2 Actuating Components—Doors that are required to be power operated shall be fitted with the necessary equipment to use electric, hydraulic, or other power sources. Actuating components include hydraulic valves, electric operators, or other suitable means of sequencing for automatic operation. Each drive unit shall be protected from injury caused by a jammed door, excessive electrical current, or excessive hydraulic or pneumatic pressure. No clutch device shall be used.

8.3 Connections and circuits shall be designed and installed so that a failure in one door circuit will not cause a failure in any other door circuit. Any failure in an alarm or indicator circuit shall not result in a loss of power for the door operation. The control system shall be such that a short or open circuit will not result in a closed door opening. The connections shall be such that leakage of salt water into local controls shall not establish a circuit that will cause a closed door to open.

9. Design of Electrical Components

9.1 Electrical components shall meet the applicable requirements of IEEE Standard 45.

9.2 Electrical motors, associated circuits, and control components located below the bulkhead deck shall be designed to operate submerged (NEMA 6 per NEMA Publication IS1.1).

9.2.1 Electric door position circuits and components located below the bulkhead deck shall be hermetically sealed, as defined in IEEE 100.

9.3 Door movement warning signals and all electrical equipment located above the bulkhead deck shall be watertight (NEMA 4 per NEMA Publication IS1.1).

10. Design of Hydraulic Components

10.1 All hydraulic components shall be designed with a minimum 4:1 factor of safety.

10.2 Hydraulic cylinders shall be designed for a bursting pressure of not less than four times the maximum allowable working pressure.

10.3 Accumulators shall be designed, constructed, and tested in accordance with Section VIII, Division 1 of the ASME Code.

10.4 Hydraulic pipe and tubing shall be stainless steel, Specification A 312/A 312M, or seamless tubing, SAE J524 or J525.

10.5 Hydraulic fluids shall have a minimum flashpoint of 315°F. In addition, the fluid shall be suitable for operation of the hydraulic system through the entire temperature range to which it may be subjected.

11. Operating Requirements

11.1 Door control systems, both manual and power, shall be designed to open and close doors against a 15° list. In addition, the operating mechanisms shall be designed to close the door against a static head equivalent to a water height of at least 1 m above the sill on the centerline of the door.

11.2 A manual control system must be designed to close a door in not more than 90 s.

11.3 All hydraulic systems shall be designed so that any hydraulic “line’’ break more than 10 ft (3 m) from the door will not prevent local power or hand closing or remote power closing of the door.

11.4 Power control systems shall close doors at an approximately uniform rate of closure, but in no case shall the closure time, from the time a door begins to move to the time it reaches the fully closed position, be less than 20 s or more than 40 s.

11.4.1 Simultaneous Closing—Means shall be provided for closing all power-operated doors simultaneously. When a large number of doors are involved, automatic means may be provided for operating the doors in sequence, with preference being given to doors in the lowest part of the vessel. The arrangement shall be such that all doors can be closed in not more than 60 s after actuation of the master mode switch.

11.5 An audible alarm, distinct from any other alarm in the area, shall give warning whenever the door is closed remotely by power and shall sound for at least 5 s, but no more than 10 s, prior to door movement for Class 3 doors. In the case of remote hand operation, the audible alarm may be configured to sound only when the door is moving. Additionally, consideration should be given to supplementing the audible alarm with a visual alarm in high noise areas.

11.6 See Supplementary Requirements for installation details.

12. Inspection and Testing of Doors and Controls

12.1 Shop Tests and Inspections:

12.1.1 Shop Test of Operating Controls—A prototype of one door and frame of each design together with its manual operating equipment, and in addition its power control equipment if a Class 3 door, shall be mounted on a structure in the shop in a vertical position. The setup for horizontal sliding doors shall be such that it can be tilted one way to demonstrate that the manual controls can close the door against a 15° list and, in addition for Class 3 doors, that electrical and hydraulic operators can close the door under 87.5 % normal voltage. In addition, a 15° opposite list shall be applied to demonstrate that the door will not overhaul and close itself and, when closed, can be opened manually and by power. Operating mechanisms shall close a door against an actual or simulated (such as with dead weight) static head equivalent to a water height of at least 1 m above the sill on the centerline of the door. Class 3 doors shall also be tested to show that a door can be unseated manually after being closed by power.
13. Certification
13.1 The manufacturer shall furnish written certification to the purchaser for each control system. The certification shall specify that the control system has been manufactured, inspected, and tested in accordance with this specification and that it has been found to meet the requirements contained herein.

14. Packaging
14.1 Components for sliding watertight door control systems shall be shipped with the door and door frame assembly with which they will be installed.

14.2 Hydraulic and electric components shall be adequately protected and shipped in reinforced cartons or crates.

14.3 All hydraulic components shall have all oil drained and proper preservation applied.

15. Keywords
15.1 door; door control; electric door control; electrohydraulic door control; manual door control; hydraulic door control; marine; marine door; mechanical door control; power door control; ship; ship door; sliding door; watertight door; watertight sliding door

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Power Supplies—The primary power supply for all required Class 3 doors shall come directly from the vessel emergency switchboard.

S2. All electric controls, indicators, and alarms shall be supplied from the final emergency power source.

S3. Power Sources—All Class 3 doors shall be provided with one of the following types of power sources:

S3.1 A centralized system with two independent power sources each consisting of a pump capable of simultaneously closing all doors in not less than 60 s. In addition, there shall be for the whole installation hydraulic accumulators of sufficient capacity to operate all of the doors at least three times, that is, close-open-close. A single failure in the hydraulic piping of the power source operating system shall not affect the power operation of more than one door.

S3.2 An individual hydraulic system for each door with one power source capable of closing the door. In addition, there shall be a hydraulic accumulator of sufficient capacity to operate the door at least three times, that is, close-open-close.

S3.3 An individual electrical system for each door with one power source capable of closing the door. In addition, there shall be a battery of sufficient capacity to operate the door at least three times, that is, close-open-close.

S4. Installation Tests and Inspection:

S4.1 Manual Control Installation Test—After a door and controls have been installed, the door shall be closed and opened by means of the manual controls at the door and shall be closed by the manual remote control. The time and effort required to close the door shall be within the limitations prescribed in 7.2 and 11.2.

S4.2 Power Control and Installation Test—If power controls are provided, the door shall be operated by the power controls from each of the control stations. The rate of closing shall be as prescribed in 11.4. The time required to simultaneously close all doors shall be as prescribed in 11.4.1. Manual controls shall also be operated to show that closure by power will not jam the door so as to prevent manual opening.

S4.3 Remote Indicator Operation—The remote indicator at the remote manual control station shall correctly show the position of the door when either manual or power operation is employed, and when power to the door is interrupted.
Standard Guide for
Shipboard Fire Detection Systems

This standard is issued under the fixed designation F 1198; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the selection, installation, maintenance, and testing of shipboard fire detection systems other than sprinkler systems.

1.2 This guide is intended for use by all persons planning, designing, installing, or using fire alarm systems onboard vessels. As it includes regulatory requirements, this guide addresses those vessels subject to regulations and ship classification rules. However, the principles stated herein are also suitable for unregulated commercial vessels, pleasure craft, military vessels, and similar vessels that are not required to meet regulations for fire detection and alarm systems.

1.3 Limitations—This guide does not constitute regulations or ship classification rules, which must be consulted when applicable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 Code of Federal Regulations:
Title 46, Part 76.25
Title 46, Part 76.30
Title 46, Part 76.33
Title 46, Part 161.002
2.2 NFPA Publications:
NFPA 72E Standard on Automatic Fire Detectors

2.3 SOLAS Regulations:
SOLAS II-2/13-1
SOLAS II-2/12

3. Terminology

3.1 Definitions:
3.1.1 accommodation space—those spaces used for public spaces, corridors, lavatories, cabins, bunkrooms, staterooms, offices, hospitals, cinemas, game and hobby rooms, barber shops, pantries containing no cooking appliances, and similar spaces.

3.1.2 alarm signalling device—an audible or visual device such as a bell, horn, siren, strobe, flashing, or rotating light used to warn of a fire condition.

3.1.3 annunciator—an audible and visual signalling panel that indicates and displays the alarm, trouble, and power conditions of the fire detection system.

3.1.4 approved—acceptable to the organization, office, or individual responsible for accepting equipment, an installation, or a procedure.

3.1.5 automated machinery space—a space containing machinery that is automated to allow: (a) periodic unattended operation by the crew; and (b) continuous manual supervision by the crew from a central room (enclosed) or remote location.

3.1.6 control panel—an electrical panel that monitors and controls all of the equipment associated with the fire detection and alarm system.

3.1.7 control space—an enclosed space within which is located a ship’s radio, main navigating equipment, emergency source of power, or the centralized fire recording or fire control equipment, but not including firefighting apparatus that must be located in the cargo area or individual pieces of firefighting equipment.

3.1.8 hazardous (classified location)—locations where fire or explosion hazards may exist due to flammable gases or vapors, flammable or combustible liquids, combustible dust, or ignitable fibers or flyings.

3.1.9 listings—equipment or materials included in a list published by an organization certified to perform product

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1 This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.


3 Available from National Fire Protection Association, One Batterymarch Park, Quincy, MA 02269-9101.

4 Available from International Maritime Organization, 4 Albert Embankment, London, England SE1 7SR.
evaluations. This organization maintains periodic inspections of production of the listed equipment or materials. The listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

3.1.10 machinery spaces of Category A—those spaces and trunks to such spaces which contain: (a) internal combustion machinery used for main propulsion; or (b) internal combustion machinery used for purposes other than main propulsion where such machinery has, in the aggregate, a total power output of not less than 500 hp (375 kW); or (c) any oil-fired boiler or oil fuel unit.

3.1.11 main vertical zones—those sections, the mean length of which does not, in general, exceed 131 ft (40 m) on any one deck, into which the hull, superstructure, and deck houses are required to be divided by fire-resisting bulkheads.

3.1.12 manually activated fire alarm box—a box containing an electrical switch which, when manually operated, sends an alarm signal to the control panel (referred to as “Manually Operated Call Points” by SOLAS).

3.1.13 RO/RO cargo space (roll on/roll off cargo spaces)—a space not normally subdivided in any way and extending to either a substantial length or the entire length of the ship in which cargo, including packaged cargo, in or on rail or road cars, vehicles (including road or rail tankers), trailers, contain-
ers, pallets, or demountable tanks (in or on similar stowage units or other receptacles), can be loaded and unloaded normally in a horizontal direction.

3.1.14 self restoring—the ability of a device to reset itself automatically after being activated.

3.1.15 service space—those spaces used for galleys, pan-
tries containing cooking appliances, lockers, mail, and specie rooms, store rooms, workshops other than those forming part of the machinery spaces, and similar spaces as well as trunks to such spaces.

3.1.16 special category space—an enclosed space above or below the bulkhead deck intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access.

3.1.17 supervised—describes an electronic method of moni-
toring the electrical continuity of the circuits and devices of a fire detection and alarm system. This is normally accomplished by constantly passing a small current through the circuits and devices.

4. Significance and Use

4.1 The purpose of a shipboard fire detection system is to provide warning so as to reduce the life safety threat from fire and to minimize the fire threat to the operation of the ship. Given that few ships are identical either in size or layout, it follows that the fire detection system will have to be custom designed accordingly. A well-designed system provides a reasonable substitute to having crew members on constant fire watch in every protected space where a fire might occur.

4.2 The basic function of the fire detection system is to automatically and reliably indicate a fire condition as quickly as is practical and to alert responsible individuals of a fire’s existence and location. This system design and application guide addresses the individual steps in the layout of the system as well as an overview of the information needed to design a system.

4.3 The U.S. Coast Guard and the International Convention for the Safety of Life at Sea (SOLAS) regulations have been stated as requirements within this guide. Additional guidelines to assure complete and effective systems or to incorporate good industry practices are stated as recommendations.

DESIGN AND APPLICATION

5. System Types

5.1 Fire detection and alarm systems used on vessels are typically of the following types:

5.1.1 Electrical automatic fire detection and alarm systems consist of a control panel, various types of fire detectors, manually actuated fire alarm boxes, audible and visual alarms, and appropriate power supplies. The control panel monitors the fire detection and alarm circuits and generates appropriate signals when an automatic fire detector or manual fire alarm box is activated.

5.1.2 A similar system without automatic fire detectors is referred to as a manual fire alarm system but is otherwise identical. Operation is initiated by individuals who activate a manually actuated fire alarm box that incorporates an electrical switch. This guide is primarily concerned with electrically operated automatic and manual fire detection and alarm systems.

5.1.3 Pneumatic fire detection systems consist of a closed length of pneumatic tubing attached to a control unit. Air chambers called heat actuated devices (HADs) are often attached to the tubing in the protected area to increase the volume and thus the sensitivity of the system. As temperature builds up in a fire, the air in the tubing expands, moving a diaphragm in the control unit. A small calibrated vent compensates for normal changes in ambient temperature. The diaphragm activates a release mechanism or a set of contacts. Because pneumatic fire detection systems are self-contained (that is, independent of outside sources of power), they are often used to activate small automatic fire extinguishing systems such as are installed in paint lockers and emergency generator enclosures. U.S. Coast Guard Requirements for pneumatic fire detection systems may be found in Title 46, Code of Federal Regulations, Part 76.30.

5.1.4 Sample extraction smoke detection systems consist of a piping system connected to a control unit with a suction blower. These systems continually draw samples from the protected spaces to the control unit where a light source and photocell monitor the sample for smoke. Sample extraction smoke detection systems are often used in cargo holds because they are less likely than individual spot-type smoke detectors to operate from dust or localized sources of smoke such as vehicle exhausts. Also, the more delicate electronics and control equipment can be located remote from the harsh environment of a cargo hold. These systems are often combined with a carbon dioxide extinguishing system, using the carbon dioxide distribution piping to draw samples from the protected areas. Detailed requirements for sample extraction smoke detection systems are contained in proposed SOLAS Regulation II-2/
6. Classification of Fire Detectors

6.1 Heat detectors are devices that sense a fixed temperature or rate of temperature rise. Heat detectors work on one of the three operating principles outlined in 6.2, 6.3, and 6.4.

6.2 A fixed temperature detector is a device that responds when its operating element becomes heated to a predetermined level. Because of the time required to heat the mass of element to its preset level, there is usually a lag time, referred to as the “thermal lag,” between the time the surrounding air reaches the operating temperature and the time the operating element reaches its preset operating temperature. There are seven temperature classification ranges. In locations where the ceiling temperature does not exceed 100°F (38°C), detectors with an operating range of 135 to 174°F (57.2 to 78.9°C) should be used. These are termed “ordinary” temperature classifications. Several types of temperature sensitive operating elements are used such as:

6.2.1 Bimetallic elements consist of two metal strips with different coefficients of expansion fused together so that heating will cause the element to deflect, making electrical contact.

6.2.2 Electrical conductivity elements are devices whose electrical resistance varies as a function of temperature.

6.2.3 Certain automatic heat detectors use fusible alloy elements or liquid expansion elements that operate at a fixed temperature. These devices are nonrestorable and are prohibited by SOLAS.

6.3 A rate-of-rise detector is a device that operates when the temperature rises at a faster than predetermined rate. Since operation does not depend on having reached a fixed temperature level, it responds to a rapid temperature rise more quickly than a fixed temperature detector. However, it does not respond to a slow developing fire regardless of how high the temperature gets. In a typical rate-of-rise detector, heated air in a chamber expands to deflect a diaphragm that operates electric contacts.

6.4 A rate of compensation detector is a device which, because of differential expansion of several components, responds when the temperature of the air surrounding the detector reaches a predetermined level, regardless of the rate at which the temperature rises. It is designed to avoid the thermal lag time that is inherent in a fixed temperature detector. This device is also known as a rate anticipation detector.

6.5 Combination heat detectors take advantage of more than one operating principle in a single detector housing. Combination fixed temperature and rate-of-rise detectors are most common.

6.6 Smoke detectors are devices that detect visible or invisible products of combustion. They work on several operating principles as follows:

6.6.1 Ionization smoke detectors have a small radioactive source that ionizes the air within a chamber, making it conductive so that a small current flows between electrodes. Smoke particles entering the chamber interfere with the free flow of ions and reduce the current, activating the detector.

6.6.2 Photoelectric smoke detectors use a light source and photocell to detect the presence of smoke. Several types may be used on ships:

6.6.2.1 In the light obscuration type of detector, smoke particles that enter between the light source and the photocell reduce the amount of light reaching the photocell, causing the detector to activate. Projected linear beam smoke detectors are light obscuration smoke detectors. The light source and photocell are separately housed, and the light beam is projected across the protected area. The alignment between transmitter and receiver is critical for proper operation of this device. Shipboard vibration and flexing may affect proper alignment.

6.6.2.2 In a photoelectric light-scattering smoke detector, the components are arranged so that light does not normally reach the photocell. When smoke particles enter the chamber, they reflect or scatter some of the light onto the photocell, activating the detector.

6.6.3 Sample extraction smoke detection systems as described in 5.1.3 operate on one of the principles covered in 6.6.2.1 and 6.6.2.2.

6.7 Flame detectors are devices that detect infrared (IR), ultraviolet (UV), or visible light produced by a fire. To avoid activation by sources or radiation other than fires such as welding, sunlight, and so forth, flame detectors are usually designed to sense light modulated at a rate characteristic of the flicker rate of flames, or to detect certain bands of IR or UV or visible radiation characteristic of flames, or some combination of these features. A combination of these features is used in some applications to reduce the probability of false alarms.

6.8 Other classifications of fire detectors include: (a) gas detectors that sense gases produced by burning substances; (b) resistance bridge smoke detectors that sense change in conductivity when smoke particles and moisture from fire are deposited on an electrical grid; (c) cloud chamber smoke detectors in which moisture is caused to condense on smoke particles drawn into a chamber; and (d) heat-sensitive cable in which high temperature softens the insulation separating two conductors, causing reduced resistance or shorting of the conductors, as well as devices that operate on other principles. Such detectors are seldom used on ships.

6.9 Combination detectors combine the principles of one or more classifications of fire detectors or detection principles in a single device. A common example is a fixed temperature-rate-of-rise heat detector.

6.10 All detectors, except sprinklers, are required by regulation to be restorable so that they can be tested for correct operation and restored to normal condition without replacing any component.
7. System Detector Coverage

7.1 Existing U.S. and international regulations for commercial vessels require automatic fire detection coverage in a wide range of spaces such as corridors, stairways, escape routes from accommodation spaces, RO-RO cargo spaces, and automated machinery spaces.

7.2 It is recommended that each accommodation space have detector coverage, including a detector in each stateroom. Consideration should also be given to placing detectors in other normally unattended areas where a fire may originate.

7.3 In addition to detectors, manually actuated fire alarm boxes must be installed throughout passageways of the accommodation, service, and control spaces and be located at each main exit and stairwell exit. Manually actuated fire alarm boxes are also required in all special category spaces.

8. Zoning

8.1 The fire detection system should be arranged into reasonably sized and clearly identified areas, called zones, to direct responding crew members to the fire’s location more quickly. Consideration should be given to having two detection circuits within a zone (that is, area or space). One detection circuit should be dedicated to manually actuated fire alarm boxes and the other dedicated to automatic fire detectors so that alarms can be distinguished from each other. Existing requirements limit individual detection zones as follows:

8.1.1 A zone is limited to a single deck level, except where an enclosed stairway is served by an individual detection zone. This zone can include multiple deck levels. Where the stairway is used as a main egress in the event of a fire, it is recommended that a stairway which joins four or more levels be served by a separate zone.

8.1.2 In passenger ships, separate zones are required on the port and starboard sides of the ship; however, regulations permit exceptions for special cases. Detection zones must be confined horizontally to one main vertical zone (MVZ).

8.1.3 Enclosed automated machinery spaces must be separately zoned from accommodation, service, and control spaces. Multiple small machinery spaces in the same general area may be grouped into a single zone.

9. Environmental Effects on Detectors

9.1 Because ships are able to move freely throughout the world, they can be subjected to many different environmental conditions. This makes it very important that the selection process of detectors, control panels, and other alarm system components be made by data and information available from manufacturers and testing laboratories.

9.2 Manufacturers shall be able to provide documentation and certification indicating the effect that environmental conditions such as temperature, humidity, pressure, air velocity, and electromagnetic interference (EMI), including radio frequency (R.F.), transients, corrosives, dust, and vibration, can have on detector sensitivity and performance.

9.3 Testing standards for detectors are usually minimum standards and, therefore, listed detectors are not all equal in performance. For example, smoke detectors may respond to smoke densities ranging from 0.5 to 4 %/ft obscuration. All smoke detectors are marked with their sensitivity. A detector with a 1 %/ft obscuration is more sensitive than a detector set at 3 %/ft. A 3 %/ft obscuration may prove more stable than a detector at 1 %/ft obscuration level. An engineering judgement shall be made as to which sensitivity is more acceptable for which application.

9.4 Temperature:

9.4.1 Smoke detectors placed in areas with temperatures approaching the upper or lower limits of the testing laboratory listing will undergo a shift in sensitivity as a result of those temperatures. Detector sensitivities will not shift equally; some detectors will change little and others will change more. The design and quality of the detector can make a difference in performance.

9.4.1.1 Generally, ionization detectors become either more sensitive in colder temperatures or less sensitive in warmer temperatures.

9.4.1.2 Generally, photoelectric detectors become either less sensitive in colder temperatures or more sensitive in warmer temperatures.

9.4.1.3 Flame detectors vary according to individual design. See the manufacturer’s information.

9.5 Relative Humidity (RH)—Relative humidity levels up to 95 % should not affect the performance of most detectors. However, condensate can present a problem to the stability of the detectors. Curves and documentation on the effects of relative humidity can be obtained from manufacturers of detectors.

9.6 Air Pressure:

9.6.1 Except for ionization detectors, atmospheric pressures usually have no measureable effect on detector sensitivity. For unusual circumstances, such as submarines or pressure chambers, refer to the manufacturer’s data.

9.6.2 Ionization detectors become less sensitive with a decrease in pressure and more sensitive with an increase in pressure. Curves and other documentation on the effects of pressure on detector sensitivity can be obtained from the manufacturer, testing laboratory, or both.

9.7 Air Velocity:

9.7.1 Continuous high air velocities or sudden gusts are major factors influencing the stability of some ionization detectors and may cause false alarms or delayed alarms. Curves and documentation on the effects of air velocities on detector sensitivity can be obtained from the manufacturer.

9.7.2 Some detectors use field adjustability to compensate the detector for sensitivity shifts caused by air velocity.

9.7.3 Some detectors use optional air shields to reduce the effects of air velocity on detector sensitivity.

9.7.4 Photoelectric detector sensitivities are not affected by air velocity.

9.8 Electromagnetic Interference (EMI)—RF energy from sources such as walkie talkies, telephones, and so forth may cause false alarms in ionization and photoelectric detectors. Documentation as to the levels of EMI and at what distances these energies are safe to use around detectors can be obtained from the manufacturer, testing laboratory, or both.

9.9 Other factors influencing the reliability and stability of a detector are as follows:
9.9.1 Unusually high concentrations of vapors from solvents and paints, aerosol sprays, steam, smoke products from kitchens, and tobaccos are some environmental contaminants that may cause false alarms to smoke detectors.

9.9.2 Cigarette lighters, welding, reflection of sunlight, and lightning are some of the environmental conditions that can prove troublesome for UV and IR flame detectors.

9.9.3 In selecting detectors, consideration should be given to the vibration and impact conditions that may occur on board ship. Consult the manufacturer’s data.

9.9.4 Location is an important factor in the reliability and stability of a detector. Avoid locating detectors too close to supply air ducts, doorways, and outside elements, that is, exposing detectors to hostile temperatures, wind gusts, and salt spray. Refer to NFPA 72E, Section 5.6, for additional information.

10. Detector Location

10.1 Type of Detector for Space—See Table 1.

10.2 Detector Location Within Space, general guidance (see NFPA 72E for more detailed instructions):

10.2.1 Determine the maximum detector spacing for smooth, low ceilings and no air flow.

10.2.1.1 Listings or approvals show maximum spacing distance between detectors.

10.2.1.2 Distances are determined by fire tests with prototype detectors.

10.2.2 For rooms over 10 ft (3 m) high, reduce thermal detector spacing according to Table 2. Add intermediate layers of detectors for spaces over 30 ft (9 m) high. For other classifications of detectors, reduced spacing should be considered as vertical height increases. Consult the manufacturer for specific requirements.

10.2.3 To determine the minimum number of detectors, set up a grid of squares using the adjusted maximum spacing with a detector at the center of each square.

10.2.4 Adjust the detector locations to avoid air diffusers which may blow heat and smoke away from detectors.

### TABLE 1 Recommended Types of Detectors

<table>
<thead>
<tr>
<th>Space</th>
<th>Heat</th>
<th>Smoke</th>
<th>Flame</th>
<th>Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodation spaces</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(including staterooms/quarters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passageways, stairways, escape routes, control spaces</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service spaces</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint lockers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cargo spaces (with explosives and adjacent space)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cargo spaces (with CO₂ fire extinguishing)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO/RO spaces</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>All other dry cargo spaces</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery spaces</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Auxiliary machinery spaces</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Heat detectors are not necessary if sampling detectors are installed.*

10.2.5 Verify that no point in the space is more than 0.7 times the reduced maximum spacing distance horizontally from the nearest detector.

10.2.6 For smoke detectors, the maximum spacing distance between detectors is 30 ft (9 m) before reductions.

10.2.7 Line-of-sight detectors such as flame detectors have a cone-shaped area of coverage emanating from each detector. The protected area must be within the cone of vision. The maximum distance from the protected area to the detector shall not exceed the distance at which a 1-ft² (0.0929-m²) gasoline fire can be detected.

10.2.8 Add appropriate detectors where necessary to assure adequate coverage of high hazard areas or to compensate for obstructions, air flow, and so forth.

10.2.9 Detectors on the overhead should be a minimum of 1.6 ft (0.5 m) away from bulkheads.

11. Alarms

11.1 Activation of Alarms:

11.1.1 Visual and audible signals at each control panel and annunciator panel shall be automatically activated upon:

11.1.1.1 Operation of any fire detector.

11.1.1.2 Operation of any manual fire alarm station.

11.1.1.3 Development of a trouble condition in the system.

11.1.1.4 Power supply failure or transfer.

11.1.2 The section or zone in which an alarm or trouble condition occurs shall be indicated visually at the main control panel and at each required annunciator panel.

11.1.3 Operation of a fire detector or manual fire alarm station in an automated machinery space shall cause an immediate audible alarm in that space as well as in sufficient other locations to be heard by the responsible engineering officer.

11.1.4 If the above fire alarms are not acknowledged within 2 min, suitable audible alarms shall sound throughout the crew accommodations, service spaces, control spaces, and machinery spaces of Category A. These audible alarms need not be an integral part of the fire detection and alarm system but may be integrated into the general alarm or other approved alarm system.

11.2 Types of Signalling Devices:

11.2.1 Alarm signalling devices shall be continuous sounding bells, sirens, horns, or similar devices except that system trouble alarms can be a buzzer or electronically generated
11.2.2 Fire alarm signals shall be distinct from all other alarms in the space in which they are located.

11.2.3 Each signalling device must be identified by a sign with red lettering at least 1 in. (25 mm) high stating “FIRE ALARM.”

11.2.4 Fire alarm signals may be transmitted through an approved ship’s general alarm system or an approved electrically supervised public address system meeting the standards for fire alarm systems, provided the fire alarm signals are separate and distinct from any other alarm signals.

11.3 Alarm Signalling Device Location and Spacing:

11.3.1 At least one fire alarm signalling device is required in each zone or each space containing more than one zone.

11.3.2 In large zones and areas with high ambient noise levels, additional alarm signalling devices shall be provided so that alarms can be heard at any point in the protected zone with all the doors closed.

11.3.3 In areas of high ambient noise levels, flashing or strobe lights must be used to attract attention to the alarm signalling device. This device shall also be labeled “FIRE ALARM” if separate from the alarm signalling device.

11.4 Manually Actuated Fire Alarm Boxes:

11.4.1 Location—A manually actuated fire alarm box shall be located at each exit from the protected zone in the normal path of exit travel from the zone.

11.4.2 Travel Distance—Additional manually actuated fire alarm boxes shall be installed so that no point in a corridor is more than 66 ft (20 m) from a box.

11.4.3 Each manually actuated fire alarm box should be clearly marked as to what the device is, when it should be utilized, and how it should be operated.

11.5 Control Panel and Remote Annunciator:

11.5.1 The main control panel shall be located on the bridge or at the fire control station.

11.5.2 If the main control panel is located at the fire control station, a supervised remote annunciator (that is, repeater) shall be located on the bridge. It is recommended that the remote annunciator display the complete system status of the main control panel.

11.5.3 The control panel and required remote annunciators shall visually display the zone of the alarm-initiating device. An instruction chart identifying what to do in the event of an alarm or trouble signal and a graphic layout clearly displaying the zone locations shall be placed on or adjacent to the control panel and required remote annunciators.

11.5.4 Additional remote annunciators may be provided at other locations such as the engine room control station. Additional optional remote annunciators installed in other areas need not display complete systems status nor have supervised wiring.

11.6 Supplementary Monitoring Functions— Although the primary function of the control panel is to receive signals from its reporting devices and annunciate them, it may also be used for other fire-related control functions. Selective zone controlled relays can be used to close fire doors, shut down air conditioning or ventilation systems, and other similar functions in the event of a fire. In cases in which the fire detection control panel is approved for sprinkler system monitoring, separate detection circuits are required for the sprinkler system.

11.7 Power:

11.7.1 It is a requirement that there be at least two sources of power supply to the fire detection system control panel. When the ship’s main and emergency sources of power are used for this purpose, separate feeders are to be wired to an approved power transfer relay at the control panel. When power drops in the main source, the transfer relay shall automatically switch to the emergency source. It shall also automatically switch back to the main source when full voltage is sensed.

11.7.2 A dedicated battery power supply at the control panel is an acceptable second source that may be used in place of the ship’s emergency source provided the batteries are automatically charged and supervised. The battery ampere hour rating shall be capable of powering the fire detection system for a minimum of 36 h on passenger ships and 18 h on other ships and still have sufficient power to energize all alarm devices for 5 min at the end of the required battery operating time.

12. Hazardous Locations

12.1 Equipment installed in hazardous areas shall be specifically approved for hazardous areas.

12.2 All circuits in hazardous areas shall be approved as intrinsically safe or explosion proof.

12.3 The number of types of devices on intrinsically safe circuits may be limited.

13. Equipment and Design Approval

13.1 Equipment Approval:

13.1.1 The control panel, detectors, manual boxes, alarms, and other devices connected to the panel shall be tested and approved by a certified organization. The certified organization should be an independent body in the business of testing and approving of fire detection and alarm systems, including quality control, approving, follow-up testing, and labeling of products.

13.1.2 In addition to the standards used for shore-based commercial fire alarm systems, additional tests shall be performed on the equipment used in a marine environment. The additional tests evaluate the ability of the equipment to operate when exposed to humidity, vibration, salt spray, extreme temperatures, inclination, and supply voltage variation.

13.2 Design Approval:

13.2.1 The system shall be designed and installed in accordance with the equipment listing. Only equipment that has been demonstrated to the listing or approval authority to be compatible shall be used.

13.2.2 If the design of the system is required to be approved by an approval authority, the design, plans, and pertinent information necessary to make a complete system design review shall be submitted to the approval authority.

14. Requisite Drawings and Materials

14.1 Complete system drawings that show the interconnections of all devices, the number and location of devices, and
how the system is configured shall be provided. System drawings are necessary so that correct installation can be undertaken, and so that after installation is completed, the system can be maintained with these drawings.

14.2 Manufacturer’s standard manuals should be provided with the system control panel. These manuals generally contain design, installation, maintenance, and troubleshooting instructions for the system. This documentation is necessary so that in the event of system problems, a source of complete information is available.

15. Installation Coordination

15.1 Retrofits—The installation of a fire detection system onboard an existing vessel is considered to be a retrofit. All of the major shipboard equipment is already in place, and the locations of obstructions are usually known. This makes it less likely for a device to be located in an area that would later be blocked or obscured from smoke, heat of flame, or manual operation.

15.2 New Construction—The timing of the installation is more critical in new ship construction. If the fire detection system is installed in the early phases of ship construction, obstructions or blockage of the equipment may occur after the devices have been installed. Coordination with the other installation activities onboard the vessel should be considered so that this does not occur. If obstructions or blockage of the fire detection devices can render the system less effective, these devices should be moved so the system is not impaired.

16. Materials

16.1 The materials that are supplied by the fire detection system vendor are generally as follows:

16.1.1 The main control panel and a remote annunciator (if specified).

16.1.2 Emergency batteries (if specified).

16.1.3 Field devices such as detectors, manually actuated fire alarm boxes, and alarm signalling devices.

16.2 The equipment that is used in the fire detection system should be from one source of supply to ensure that the devices that are being used are compatible with the main control panel. Compatibility is important so that the system operation is not impaired under alarm or any other conditions.

16.3 Equipment that may be supplied by the installer includes:

16.3.1 Cable:

16.3.1.1 Cable should be used that conforms to the manufacturer’s recommended types and regulations. The conductor should be continuous between devices (that is, splices should not be made between devices).

16.3.1.2 In addition, a T-tap on a wire should not be made because this will affect the ability of the control panel to supervise all of the conductors (the limitation on T-Taps may not apply to multiplex systems with addressable detectors). This occurs because supervision normally needs a loop with an end of line resistor to monitor continuity or shorting of the circuit.

16.3.2 Fasteners—The recommendations of the equipment manufacturer should be followed when mounting and connecting the equipment that was supplied by the vendor.

16.4 The materials that are supplied by the vendor and by the installer should be examined before installation to determine that the correct quantities are available and that the condition of the devices has not been affected as a result of shipping or storage before the installation of the devices. This is necessary so that the system can be installed in a continuous fashion with the likelihood of running out of equipment or using questionable equipment minimized.

17. Location of Equipment

17.1 The main panel and remote annunciator (if required) should be located in an area with low fire risk. The control units should be located on a vertical bulkhead in an unobstructed location. The height of the cabinet should be at a convenient height from the deck for ease of operator usage and visual checking. The device should be out of the way so mechanical damage is unlikely. If mechanical damage could occur to the control unit, a barrier should be installed to protect the unit.

17.2 Instruction Chart and Graphic Layout—If not shown on the face of the control panel, an instruction chart and graphic layout, as described in 11.5.3, should be placed at a convenient height next to the control panel and remote annunciator (if specified) and should not be obstructed from view.

17.3 Alarm Signalling Device:

17.3.1 Alarm signalling devices should be located throughout each protected zone so the alarm can be heard by anyone within that zone (see 11.3 for requirements).

17.3.2 A sign should be placed adjacent to the alarm signalling device as specified in 11.2.3.

17.3.3 Audibility at sea shall be verified in each protected zone with all mechanical equipment operating and all doors shut.

17.4 Installation of Manually Actuated Fire Alarm Boxes—Manually actuated fire alarm boxes should be installed at unobstructed points. The boxes should be located at the exit points, as described in 11.4, to the spaces and be marked.

17.5 Detectors:

17.5.1 The detectors should be located away from sources that normally produce heat or smoke which may cause a false alarm of the detector. The spacing of the detectors should be to the system specification, published information on the detectors, the installation drawings, and Section 10.

17.5.2 The detectors should be firmly mounted on the surface. The detector should put no stress on the field wiring which attaches the device to the control panel. The detectors should be positioned according to the manufacturer’s recommendations. The detectors should be placed away from air flows which could affect the performance of the detectors.

17.6 Batteries:

17.6.1 In some cases, batteries are supplied separately from the control panel. If separate batteries are supplied, they should be placed as close as possible and adjacent to the control panel.

17.6.2 In locating this battery box, caution should be exercised since the batteries may emit flammable gases during charging. Generally, these flammable gases are given off in small quantities, but the air flow should be such that these gases are not trapped in a small space, which could cause a hazard.
TESTING AND MAINTENANCE

18. General Information

18.1 Periodic maintenance and testing should be performed to ensure that the fire detection system is completely operable at all times. All components of the detection system should be tested at least once every six months, while some components require testing more frequently. Specific testing and maintenance intervals, and the recommended documentation, are covered in this section.

18.2 Complete installation, operation, and maintenance manuals for all components of the system should be kept on board the vessel. The manufacturer’s specified procedures shall be adhered to when performing tests or routine maintenance. If the manufacturer’s recommended service intervals are longer than those specified herein, the intervals specified in this section govern.

18.3 The operator of the vessel is directly responsible for performing maintenance and testing at the required intervals, and for keeping current the related documentation. The vessel owner should inspect these documents as necessary, to ensure that maintenance and testing have been performed in accordance with these recommendations.

18.4 In addition to keeping records of maintenance and testing intervals, a system log (see the sample in Appendix X1) should include a record by time and date of any system occurrence. All alarms and trouble signals, explained or unexplained, should be recorded by the zone. When possible, the detector or other device that initiated the alarm and cause should be recorded. This information is essential for trouble-shooting.

18.5 All equipment necessary to conduct the tests specified in this section should be available onboard the vessel at all times.

19. Testing Instructions

19.1 Functional tests should be performed on all components of the system for system commissioning and at a frequency recommended by the manufacturer but not less than specified in Table 3. A testing and maintenance log similar to Appendix X2 should be kept for the fire alarm system. The manufacturer’s maintenance and testing procedure should be followed and should include at least the following:

19.1.1 Smoke Detectors—Each smoke detector in the system should be tested separately by introducing smoke or other appropriate test gas. The receipt of an alarm condition should be verified at the control unit. If the detectors have a sensitivity measurement feature, readings should be taken and recorded. Detectors that are more sensitive than the manufacturer’s recommendation should be adjusted to the proper sensitivity or replaced.

19.1.2 Heat Detectors—Each detector should be tested separately by applying heat according to the manufacturer’s recommended procedure. The receipt of an alarm condition should be verified at the control unit.

19.1.3 Manually Actuated Fire Alarm Boxes—Each box should be operated and the receipt of an alarm condition verified at the control unit.

19.1.4 Flame Detectors—Each detector should be exposed to radiation from open flame or appropriate test lamps and the receipt of an alarm condition verified at the control unit.

19.1.5 Alarm Signalling Devices—Each device shall be operated during the testing of detectors and manually operated fire alarm boxes. The proper operation and sound levels should be verified. Separate manually activated alarm systems to summon the crew or notify passengers of fire, including the general alarm if so used, should also be tested.

19.1.6 Fire and Smoke Doors and Dampers—Operate the alarm system and verify proper operation of automatically operated doors and dampers. Visually inspect to verify that there are no obstructions, door props, and so forth to hinder operation.

19.1.7 Control Panel—In addition to the functional tests previously described, continuity on each external supervised circuit should be interrupted and a trouble indication observed with each interruption. Primary operating power should be interrupted and the control unit observed for proper operation and standby power. If multiple levels of standby power are provided, standby operation at all levels should be observed. It should be verified that appropriate indications of abnormal conditions occur during power interruption.

19.1.8 Sample Extraction Smoke Detection Systems—Sample systems should be tested by introducing smoke into each sampling point and observing an alarm indicating with each introduction. The system should be allowed to clear thoroughly between smoke tests of each sampling point. All supervisory functions should be tested by stimulating the necessary abnormal conditions and observing the proper indications at the control unit. As a minimum, the supervisory functions to be tested shall include:

19.1.8.1 Blowers, operating properly.

19.1.8.2 Primary Power, normal.

19.1.8.3 Annunciator (Repeater) Panel, light supervision.

19.1.8.4 Internal Power Circuitry, normal.

19.1.8.5 Photoelectric Lamps, normal.

19.1.8.6 Detection Module, which the sample air is drawn through, working properly.

19.1.9 Standby Batteries—Tests of batteries should only be performed when batteries are fully charged. The batteries should be subject to loading and the voltage observed on the battery after the loading has been applied. The manufacturer’s recommendations should be followed regarding the amount and duration of the load before voltage measurement. Check

TABLE 3 System Test Intervals

<table>
<thead>
<tr>
<th>Component</th>
<th>Interval Between Tests, months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke detectors</td>
<td>6</td>
</tr>
<tr>
<td>Heat detectors</td>
<td>6</td>
</tr>
<tr>
<td>Manually actuated fire alarm boxes</td>
<td>6</td>
</tr>
<tr>
<td>Flame detectors</td>
<td>6</td>
</tr>
<tr>
<td>Alarm signalling devices</td>
<td>6</td>
</tr>
<tr>
<td>Control panel</td>
<td>6</td>
</tr>
<tr>
<td>Sample extraction smoke detection systems</td>
<td>6</td>
</tr>
<tr>
<td>Standby batteries</td>
<td>2</td>
</tr>
<tr>
<td>Smoke doors and dampers</td>
<td>6^</td>
</tr>
</tbody>
</table>

^Visually inspect every month.
20. Maintenance

20.1 While the testing procedures previously described are of primary importance to ensure system integrity, proper operation of the system also requires that detection devices be cleaned regularly. Detection devices also need to be checked to ensure they have not been damaged, covered, or painted, which could effect the response to a fire condition. Recommended service intervals are as follows:

20.1.1 Smoke Detectors—Smoke detectors, both ionization and photoelectric, should be cleaned at intervals no greater than six months, and more frequently depending on the amount of airborne contaminants in the environment. The manufacturer’s recommended procedure should be followed to perform cleaning.

20.1.2 Flame (Optical) Detectors—The lenses of flame detectors should be cleaned at intervals not to exceed two months, or more frequently if conditions warrant. The manufacturer’s recommendations should be followed when performing the cleaning.

20.1.3 Heat Detectors—Heat detectors should be inspected at six-month intervals and cleaned if necessary to prevent any buildup of foreign material on the outside that would hinder the ability of the device to detect a fire condition.

21. Testing After Actual Fire Event

21.1 In the event of an actual fire, all fire detection equipment and wiring associated with the system in the area involved should be thoroughly tested and examined immediately after cleanup. The testing of the detectors and other system operating equipment should follow normal test and maintenance procedures.

21.2 Even though the continuity of the wiring and connectors is automatically supervised by the control panel, wires and cable should be examined for any damage that might cause a later failure. All important details of this fire should be recorded in the system log (see Appendix X1).

22. Testing and Maintenance Documentation

22.1 Appendix X2 provides a recommended format to be used whenever routine or nonroutine maintenance and testing are performed on the system.
Standard Specification for
Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150°F Maximum)\textsuperscript{1}

1. Scope

1.1 This specification covers all cast strainers and welded strainers in services up to 150 psig and 150°F (1 MPa and 65°C). For welded strainers used in services above 150 psig and 150°F, see Specification F 1200.

1.2 This standard provides the minimum requirements for the design, fabrication, rating, marking, and testing of cast and welded pipe line strainers for services above 0°F (−18°C).

1.3 Strainers manufactured to this specification are acceptable for use in the marine environment.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 8, of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
F 1200 Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150°F)\textsuperscript{2}

2.2 ANSI Standards:\textsuperscript{3}
B2.1 Pipe Threads
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable Iron Threaded Fittings
B16.4 Cast Iron Threaded Fittings
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.15 Cast Bronze Threaded Fittings
B16.24 Bronze Pipe Flanges and Flanged Fittings
B16.25 Buttwelding Ends
B31.1 Power Piping

2.3 MSS Standards:\textsuperscript{4}
SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings
SP-63 High Strength Wrought Welding Fittings

2.4 ASME Standard:\textsuperscript{5}
ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels

3. Terminology

3.1 Definitions:

3.1.1 basket or element—the replaceable part in a strainer that performs the barrier separation of solid particles from flowing fluid. It is normally removable for cleaning and servicing and can be furnished in a wide variety of materials, particle size removal capability, straining area, and types of construction. Interchangeable baskets or elements are normally available for a given make, model, and size strainer.

3.1.2 maximum allowable working pressure (MAWP)—the highest internal pressure that the strainer can be subjected to in service. The maximum nonshock working pressure for which a strainer is rated by the manufacturer.

3.1.3 maximum design temperature—the maximum temperature for which a strainer is rated by the manufacturer.

3.1.4 strainer—a device which, when installed in a pipe line, provides a mechanical means of removing solids from a flowing liquid or gas by using a barrier element.

3.1.5 straining open area—the net effective open area of the clean element through which the fluid can pass.

4. Classification

4.1 Strainers may be classified into three general construction categories, simplex, duplex (or multiplex), and automatic (self-cleaning), as follows:

4.1.1 Simplex—A strainer consisting of a single basket or element chamber that normally requires the flow through the unit to be shut down before cleaning.

4.1.1.1 Classifications of simplex strainers based on port alignment relative to basket or element chamber are Y, T, Z, and others.

\textsuperscript{1} This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.

\textsuperscript{2} Annual Book of ASTM Standards, Vol 01.07.

\textsuperscript{3} Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

\textsuperscript{4} Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

\textsuperscript{5} Available from Manufacturers Standardization Society of the Valve and Fitting Industry, Inc., 1815 N. Fort Myer Dr., Arlington, VA 22209.
4.1.2 Duplex (or Multiplex)—A strainer usually consisting of at least two basket or element chambers separated by a valve (or valving) that permits continuous flow of fluid through one chamber while the other is accessible for cleaning.

4.1.3 Automatic (Self-Cleaning)—A strainer providing some means for back-flushing or cleaning of the straining element while the unit is in service. It can have one or more elements and may require periodic shutdown for maintenance and inspection.

4.2 Strainers may be further classified by pressure ratings and types of port connections, port alignments relative to unit center lines, cover closures, valve types (in duplex), types of baskets or elements, materials of construction, and other features of design.

5. Ordering Information

5.1 Orders for products under this specification shall include the following information as applicable. If a manufacturer’s standardized product is being ordered, include all data needed by the manufacturer to define the product.

5.1.1 Make.
5.1.2 Model (simplex or duplex).
5.1.3 Port size.
5.1.4 Port connections.
5.1.5 Maximum allowable pressure/temperature rating.
5.1.6 Body and cover material.
5.1.7 Type of cover closure.
5.1.8 Basket (element) material.
5.1.9 Basket hole size.
5.1.10 Optional design features.
5.1.11 Certification (see 8.1.2.1 and Section 9).
5.1.12 This ASTM standard designation number.
5.1.13 Additional requirements or testing as contracted by the manufacturer and purchaser.

5.2 If a product is to be specified by performance criteria rather than model description, then the following should be specified:

5.2.1 Maximum allowable clean pressure loss at a given flow capacity of a given liquid at a given velocity.
5.2.2 Temperature and pressure.
5.2.3 Straining area.
5.2.4 Minimum basket rupture differential pressure (see 7.4).
5.2.5 Maximum valve seepage rates (see 7.3).
5.2.6 Certification (see 6.2, 8.1.2.1, and Section 9).
5.2.7 For self-cleaning strainers, specify basket cleaning effectiveness and endurance testing.

5.3 In general, the standard product description should not be mixed with the performance criteria because conflicting specifications can result (for example, maximum allowable pressure loss inconsistent with product size).

6. Materials and Manufacture

6.1 Strainer housings, as well as any pressure-retaining parts, including bolting used for pressure retention, shall be constructed of materials listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code (hereafter called ASME Code) or ANSI/ASME B31.1. Bolts, screws, and fasteners in contact with interior fluid shall be of appropriate corrosion-resistant material.

6.2 The pressure ratings established under this specification are based on materials of high quality produced under regular control of chemical and mechanical properties by a recognized process. The manufacturer shall be prepared to submit a certificate of compliance verifying that his product has been so produced and that it has been manufactured from material whose chemical and mechanical properties are at least equal to the requirements of the appropriate standard or specification.

6.3 For materials not having values of allowable stress tabulated in Section VIII, Division 1 of the ASME Code, allowable stresses shall be determined in accordance with the procedures outlined in Subsection C and Appendix P of that section. Where it can be shown that the values of allowable stress listed for a particular material in one product form (because of similar chemistry, mechanical properties, heat treatment, and so forth) are applicable to the same material in an unlisted product form, the listed values of allowable stress may be used.

6.4 Seals and parts, other than pressure-retaining parts and bolting used for pressure retention, shall be of materials suitable for the service.

6.5 Users are cautioned against applications with fluids which may react chemically with any materials used in these products in contact with the fluid.

6.6 Cast iron shall be limited to services below 450°F (232°C). Cast iron fittings conforming to B16.1 and B16.4 are limited to Class 125 and Class 250.

7. Other Requirements

7.1 The maximum allowable working pressure (MAWP) and maximum design temperature (MAT) rating of strainers covered under this specification shall be established by at least one of the following methods:

7.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII of the ASME Code. If burst-type tests as outlined in paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of B to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture. Safety of personnel shall be given serious consideration when conducting proof tests. Components that have been subjected to a proof test shall not be offered for sale.

7.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1 of the ASME Code.

7.1.3 Extensive and successful performance experience under comparable service conditions with similar materials may be used as a basis for rating provided all other provisions of this specification are met.

7.2 Pipe end connections for strainers shall be in accordance with one of the standards listed in 2.2 and 2.3 or as agreed upon between the purchaser and manufacturer (see 5.1.13). Threaded pipe connections shall be limited to the following pressures:

- ¼ in. (19 mm) NPS and below . . . 1500 psig (10.3 MPa) max
1. Strainers shall be capable of handling 10 psig (0.069 MPa) differential pressure without rupturing or such other differential pressure as contracted by the manufacturer and purchaser (see 5.2.4) for the application involved.

2. Test Methods

8.1 Test all strainers by one of the following methods:

8.1.1 Conduct a hydrostatic test at 1 1/2 times the 100°F (37°C) rated MAWP of the strainer. Perform the test with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F. The minimum duration of the test shall be 15 s for strainers less than 2-in. (50-mm) nominal pipe size (NPS), 1 min for strainers 2 1/2 through 8 in. (63 through 203 mm), and 3 min for larger sizes. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.1.2 Strainers 2-in. (50-mm) NPS and smaller with other than flanged connections may, at the option of the manufacturer, be air tested to the lesser of 1.2 times the MAWP or 80 psig (0.55 MPa). The minimum duration of the test shall be 15 s. Visually detectable leakage is not acceptable.

8.1.2.1 If this option is exercised, the manufacturer shall be able to certify that a prototype of the same size strainer was subjected to a hydrostatic test in accordance with 8.1.1.

9. Certification

9.1 When specified in the purchase order or contract, the manufacturer’s certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

10. Product Marking

10.1 Each strainer shall have a securely attached name plate or other permanent marking indicating:

10.1.1 Manufacturer’s name or trademark.
10.1.2 Maximum allowable working pressure.
10.1.3 Size (end connection NPS size).
10.1.4 Direction of flow (by an arrow or the word “inlet,” “outlet,” or both).
10.1.5 ASTM designation of this specification.

11. Quality Assurance

11.1 The strainer manufacturer shall maintain the quality of the strainers that are designed, tested, and marked in accordance with this specification. At no time shall a strainer be sold indicating that it meets the requirements of this specification if it does not meet the requirements herein.

12. Keywords

12.1 automatic strainer; cast pipe line strainers; cast strainers; duplex strainer; simplex strainer; strainer; welded pipe line strainers; welded strainers
Standard Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150°F)\textsuperscript{1}

This standard is issued under the fixed designation F 1200; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers welded strainers in services above 150 psig or 150°F (1 MPa and 65°C). For welded strainers in services at or below these ratings and cast strainers, see Specification F 1199.

1.2 This specification provides the minimum requirements for the design fabrication, rating, marking, and testing of welded pipe line strainers for services above 0°F (−18°C).

1.3 Strainers manufactured to this specification are acceptable for use in the marine environment.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 8, of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester\textsuperscript{2}

F 722 Specification for Welded Joints for Shipboard Piping Systems\textsuperscript{3}

F 1199 Specification for Cast (all Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150°F Maximum)\textsuperscript{3}

2.2 ANSI Standards:\textsuperscript{4}

B2.1 Pipe Threads

B16.1 Cast Iron Pipe Flanges and Flanged Fittings

B16.3 Malleable Iron Threaded Fittings

B16.4 Cast Iron Threaded Fittings

B16.5 Steel Pipe Flanges and Flanged Fittings

B16.11 Forged Steel Fittings, Socket-Welding and Threaded

B16.15 Cast Bronze Threaded Fittings

B16.24 Bronze Pipe Flanges and Flanged Fittings

B16.25 Buttwelding Ends

B31.1 Power Piping

2.3 MSS Standards:\textsuperscript{5}

SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings

SP-63 High Strength Wrought Welding Fittings

2.4 ASME Standard:\textsuperscript{6}

ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Pressure Vessels

ASME Boiler and Pressure Vessel Code: Section IX, Welding and Brazing Qualifications

3. Terminology

3.1 Definitions:

3.1.1 basket or element— the replaceable part in a strainer that performs the barrier separation of solid particles from flowing fluid. It is normally removable for cleaning and servicing and can be furnished in a wide variety of materials, particle size removal capability, straining area, and types of construction. Interchangeable baskets or elements are normally available for a given make, model, and size strainer.

3.1.2 maximum allowable working pressure (MAWP)—the highest internal pressure that the strainer can be subjected to in service. The maximum nonshock working pressure for which a strainer is rated by the manufacturer.

3.1.3 maximum design temperature—the maximum temperature (MAT) for which the strainer is rated by the manufacturer.

3.1.4 strainer—a device which, when installed in a pipe line, provides a mechanical means of removing solids from a flowing liquid or gas by using a barrier element.

3.1.5 straining open area—the net effective open area of the clean element through which the fluid can pass.

\textsuperscript{1} This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.

\textsuperscript{2} Annual Book of ASTM Standards, Vol 05.01.

\textsuperscript{3} Annual Book of ASTM Standards, Vol 01.07.

\textsuperscript{4} Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

\textsuperscript{5} Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

\textsuperscript{6} Available from Manufacturers Standardization Society of the Valve and Fitting Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.
4. Classification

4.1 Strainers may be classified into three general construction categories, simplex, duplex (or multiplex), and automatic (self-cleaning), as follows:

4.1.1 Simplex—A strainer consisting of a single basket or element chamber that normally requires the flow through the unit to be shut down before cleaning.

4.1.1.1 Classifications of simplex strainers based on port alignment relative to basket or element chamber are Y, T, Z, and others.

4.1.2 Duplex (or Multiplex)—A strainer usually consisting of at least two basket or element chambers separated by a valve (or valving) that permits continuous flow of fluid through one chamber while the other is accessible for cleaning.

4.1.3 Automatic (Self-Cleaning)—A strainer providing some means for back-flushing or cleaning of the straining element while the unit is in service. It can have one or more elements and may require periodic shutdown for maintenance and inspection.

4.2 Strainers may be further classified by pressure ratings and types of port connections, port alignments relative to unit center lines, cover closures, valve types (in duplex), types of baskets or elements, materials of construction, and other features of design.

5. Ordering Information

5.1 Orders for products under this specification shall include the following information as applicable. If a manufacturer's standardized product is being ordered, include all data needed by the manufacturer to define the product.

5.1.1 Make.

5.1.2 Model (simplex or duplex).

5.1.3 Port size.

5.1.4 Port connections.

5.1.5 Maximum allowable working pressure/temperature rating.

5.1.6 Body and cover material.

5.1.7 Type of cover closure.

5.1.8 Basket (element) material.

5.1.9 Basket hole size.

5.1.10 Optional design features.

5.1.11 Certification (see 6.4, 8.1.2.1, and Section 9).

5.1.12 Nondestructive examination requirements (see 8.2).

5.1.13 This ASTM standard designation number.

5.1.14 Additional requirements or testing as contracted by the manufacturer and purchaser.

5.2 If a product is to be specified by performance criteria rather than model description, then the following should be specified:

5.2.1 Maximum allowable clean pressure loss at a given flow capacity of a given liquid at a given viscosity.

5.2.2 Temperature and pressure.

5.2.3 Straining area.

5.2.4 Minimum basket rupture differential pressure (see 7.9).

5.2.5 Maximum valve seepage rates (see 7.8).

5.2.6 Certification (see 6.4, 8.1.2.1, and Section 9).

5.2.7 For self-cleaning strainers, specify basket cleaning effectiveness and endurance testing.

5.3 In general, the standard product description should not be mixed with the performance criteria because conflicting specifications can result (for example, maximum allowable pressure loss inconsistent with product size).

6. Materials and Manufacture

6.1 Strainer housings, as well as any pressure-retaining parts, including bolting used for pressure retention, shall be constructed of materials listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code (hereafter called ASME Code) or ANSI/ASME B3.1. Bolts, screws, and fasteners in contact with interior fluid shall be of appropriate corrosion-resistant material.

6.2 The pressure ratings established under this specification are based on materials of high quality produced under regular control of chemical and mechanical properties by a recognized process. The manufacturer shall be prepared to submit a certificate of compliance verifying that his product has been manufactured from material whose chemical and mechanical properties are at least equal to the requirements of an acceptable standard or specification.

6.3 For materials not having values of allowable stress tabulated in Section VIII, Division 1 of the ASME Code, allowable stresses shall be determined in accordance with the procedures outlined in Subsection C and Appendix P of that section. Where it can be shown that the values of allowable stress listed for a particular material in one product form (because of similar chemistry, mechanical properties, heat treatment, and so forth) are applicable to the same material in an unlotted product form, the listed values of allowable stress may be used.

6.4 Seals and parts, other than pressure-retaining parts and bolting used for pressure retention, shall be of materials suitable for the service.

6.5 Users are cautioned against applications with fluids which may react chemically with any materials used in these products in contact with the fluid.

7. Other Requirements

7.1 The maximum allowable working pressure (MAWP) and maximum design temperature rating of strainers covered under this specification shall be established by at least one of the following methods:

7.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII of the ASME Code. If burst-type tests as outlined in paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of B to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture. Safety of personnel shall be given serious consideration when conducting proof tests. Components that have been subjected to a proof test shall not be offered for sale.

7.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1 of the ASME Code.
7.1.3 Extensive and successful performance experience under comparable service conditions with similar materials may be used as a basis for rating provided all other provisions of this specification are met.

7.2 Strainers may be cast, forged, or fabricated of plates, tubes, or pipes. Welding on pressure-retaining components shall be as specified below.

7.3 Welded joint design details shall be in accordance with Section VIII, Division 1 of the ASME Code except as noted in 7.4 and 7.5. Supplemental radiography requirements are presented in Section 8 of this specification. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code. Except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.

7.4 Inlet and outlet connections consisting of welded flanges and fittings shall be in accordance with Specification F 722. Pipe end connections for strainers shall be in accordance with one of the standards listed in 2.2 or 2.3. Where radiography is required by 8.2.2, all welded inlet and outlet connections shall be butt-weld joints as required by Specification F 722 for Class 1 piping systems.

7.5 Welds on strainers greater than 6-in. (152-mm) internal diameter or 1.5-ft³ (0.042-m³) net internal volume rated above 600 psi (4.14 MPa) or 400°F (204°C) shall be of the following types as listed in Table UW-12 of the ASME Code: Type (1) for Category A joints; Types (1) or (2) for Category B joints; and all Category C and D joints shall be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall. Welded joint categories are defined under UW-3 of the ASME Code.

7.6 Post-weld heat treatment shall be in accordance with Section VIII, Division 1 except as noted in 7.6.1.

7.6.1 Strainers fabricated of carbon or low alloy steel, greater than 6-in. (152-mm) internal diameter or 1.5-ft³ (0.042-m³) net internal volume, rated above 600 psi (4.14 MPa) or 400°F (204°C), shall be post-weld, heat-treated regardless of thickness.

7.7 Threaded pipe connections shall be limited to the following pressures:

- ¾ in. (19 mm) NPS and below...1500 psig (10.34 MPa) max
- 1 in. (25 mm) NPS and below...1200 psig (8.27 MPa) max
- 2 in. (50 mm) NPS and below...600 psig (4.14 MPa) max
- 3 in. (76 mm) NPS and below...400 psig (2.76 MPa) max

7.7.1 Threaded pipe joints above 2-in. (50-mm) nominal pipe size (NPS) shall not be used in systems that require radiographic examination listed in 8.2.2.

7.8 Duplex (or multiplex) strainer valve seepage rates shall be minimized to prevent undue spillage of fluid under normal operating conditions while the element is being serviced or cleaned in accordance with the manufacturer’s procedures. Maximum seepage rates with a specified liquid at a specified pressure and temperature may be as contracted by the manufacturer and purchaser (see 5.2.5), and provision may be made to include a test to determine acceptability before acceptance for a given application.

7.9 Baskets or elements shall withstand a minimum of 10-psi (0.069-MPa) differential pressure without rupturing or such other differential pressure as contracted by manufacturer and purchaser (see 5.2.4) for the application involved.

8. Test Methods

8.1 Test all strainers by one of the following methods:

8.1.1 Conduct a hydrostatic test at 1½ times the 100°F (38°C) rated MAWP of the strainer. Perform the test with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 15 s for strainers less than 2-in. (50-mm) NPS, 1 min for strainers 2½ through 8 in. (63 through 203 mm), and 3 min for larger sizes. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.1.2 Strainers of 2-in. (50-mm) NPS and smaller with other than flanged connections may, at the option of the manufacturer, be air tested to the lesser of 1.2 times MAWP or 80 psig (0.55 MPa). The minimum duration of the test shall be 15 s. Visually detectable leakage is not acceptable.

8.1.2.1 If this option is exercised, the manufacturer shall be able to certify that a prototype of the same size strainer was subjected to a hydrostatic test in accordance with 8.1.1.

8.2 Examine welds as follows:

8.2.1 Visually examine all welds in accordance with ANSI B31.1.

8.2.2 Welded inlet and outlet connections of a strainer that are equal to or greater than 4-in. (100-mm) nominal diameter or 0.375-in. (9.5-mm) nominal wall thickness in the following services shall be 100 % radiographically examined in accordance with UW-51 of the ASME Code.

<table>
<thead>
<tr>
<th>Service</th>
<th>Pressure, psig (MPa)</th>
<th>Temperature, °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied flammable gas</td>
<td>above 150 (10.03)</td>
<td>... and ... above 0 (−18)</td>
</tr>
<tr>
<td>Fuels</td>
<td>above 150 (10.03)</td>
<td>... or ... above 150 (66)</td>
</tr>
<tr>
<td>Liquids with a flash pointA</td>
<td>above 150 (10.03)</td>
<td>... or ... above 150 (66)</td>
</tr>
<tr>
<td>150°F (66°C) or below</td>
<td>above 225 (1.55)</td>
<td>... or ... above 400 (204)</td>
</tr>
<tr>
<td>Liquids with a flash pointB</td>
<td>above 150 (10.03)</td>
<td>... or ... above 150 (66)</td>
</tr>
<tr>
<td>150°F (66°C)</td>
<td>above 225 (1.55)</td>
<td>... or ... above 400 (204)</td>
</tr>
<tr>
<td>Steam, gases, and vapors</td>
<td>above 150 (10.03)</td>
<td>... or ... above 650 (343)</td>
</tr>
<tr>
<td>Water</td>
<td>above 225 (1.55)</td>
<td>... or ... above 350 (177)</td>
</tr>
</tbody>
</table>

A Flash point measured in accordance with Test Methods D 93.
B Includes lubricating oils, hydraulic fluids, and heat transfer oils.

8.2.3 All butt-welds on strainers greater than 6-in. (152-mm) internal diameter or 1.5-ft³(0.042-m³) net internal volume rated above 600 psi (4.14 MPa) or 400°F (204°C) shall be fully radiographed in accordance with UW-51 of the ASME Code.

9. Certification

9.1 When specified in the purchase order or contract, the manufacturer’s certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

10. Product Marking

10.1 Each strainer shall have a securely attached name plate or other permanent marking indicating:

10.1.1 Manufacturer’s name or trademark.

10.1.2 Maximum allowable working pressure.
10.1.3 Size (end connection NPS size).
10.1.4 Direction of flow (by an arrow or the word “inlet,” “outlet,” or both).
10.1.5 ASTM designation number of this specification.
   10.1.5.1 An “X” shall be placed after the ASTM designation if the welds are radiographed in accordance with Section 8 of this specification.

11. Quality Assurance
   11.1 The strainer manufacturer shall maintain the quality of the strainers that are designed, tested, and marked in accordance with this specification. At no time shall a strainer be sold indicating that it meets the requirements of this specification if it does not meet the requirements herein.

12. Keywords
   12.1 cast strainers; marine strainer; strainer; welded strainers
Standard Specification for
Fluid Conditioner Fittings in Piping Applications Above 0°F

This standard is issued under the fixed designation F 1201; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides the minimum requirements for pressure-retaining components of fluid conditioner fittings. It addresses the pressure-retaining component design, fabrication, rating, marking, and testing.

1.2 This specification is not intended to override any of the present fluid conditioner fitting specifications specific to devices such as strainers, filters, and traps but should be used for devices for which a specific specification does not apply.

1.3 This specification provides sufficient requirements to allow a fluid conditioner fitting to be used in the marine environment.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 7, of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D 93 Test Methods for Flash Point by Pensky-Martens
Closed Cup Tester²
F 722 Specification for Welded Joints for Shipboard Piping Systems³

2.2 ANSI Standards:⁴
B2.1 Pipe Threads
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable Iron Threaded Fittings
B16.4 Cast Iron Threaded Fittings
B16.5 Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.15 Cast Bronze Threaded Fittings
B16.24 Bronze Pipe Flanges and Flanged Fittings
B16.25 Buttwelding Ends
B31.1 Power Piping
2.3 MSS Standards:⁵
SP-44 Steel Pipe Flanges
SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings
SP-61 Pressure Testing of Steel Valves
SP-67 Butterfly Valves
2.4 ASME Standard:⁶
ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Pressure Vessels
ASME Boiler and Pressure Vessel Code: Section IX, Welding and Brazing Qualifications

3. Terminology

3.1 Definitions:
3.1.1 fluid conditioner fitting—a device, other than a valve or pipe or pipe joining fitting, installed in a pressure piping system, that monitors or provides for the monitoring of the fluid, or otherwise operates on or alters the condition of the fluid.

3.1.2 maximum allowable working pressure (MAWP)—the highest internal pressure at the maximum design temperature that the fluid conditioner fitting can be safely subjected to in service.

3.1.3 maximum design temperature—the maximum temperature for which the fluid conditioner fitting is rated by the manufacturer.

3.1.4 multiplex fluid conditioner fitting—a fluid conditioner fitting that is made up of multiples of a single unit connected by either manifolding, piping, tubes, or valves.

³ This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


² Annual Book of ASTM Standards, Vol 05.01.


⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

⁵ Available from Manufacturers Standardization Society of the Valve and Fitting Industry, 1815 N. Forth Myer Dr., Arlington, VA 22209.

⁶ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.
4. Classification

4.1 Class I—Fluid conditioner fitting meeting the following requirements:

<table>
<thead>
<tr>
<th>Service</th>
<th>Pressure, psig (MPa)</th>
<th>Temperature, °F (°C)</th>
</tr>
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</tr>
<tr>
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<td>above 150 (66)</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Liquids with a flash point b</td>
<td>above 225 (1.55) . . .</td>
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</tr>
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<td></td>
<td></td>
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<td>Steam, gases, and vapors</td>
<td>above 150 (1.03) . . .</td>
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</tr>
<tr>
<td>Water</td>
<td>above 225 (1.55) . . .</td>
<td>above 350 (177)</td>
</tr>
</tbody>
</table>

a Flash point measured in accordance with Test Methods D 93.
b Includes lubricating oils, hydraulic fluids, and heat transfer oils.

4.2 Class II—All other fluid conditioner fittings.

5. Materials and Manufacture

5.1 Pressure-retaining parts shall be constructed of materials listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code (hereafter called the ASME Code) or ANSI B31.1. Nonmetallic materials may be used for pressure-retaining parts provided the material is suitable for the intended service and is compatible with the fluid to be conducted.

5.2 Fluid conditioner fittings intended for flammable service with nonmetallic materials or metallic materials having a solidus to liquidus temperature below 1700°F (927°C) shall pass the prototype fire test in 7.2.

5.3 Bolting materials shall be at least equal to those listed in Table 1 of ANSI B16.5 or Table 126.1 of ANSI B31.1. Bolts, screws, and fasteners in contact with interior fluid shall be compatible with the fluid. Carbon steel bolting shall not be used in services rated above 500°F (260°C).

5.4 Gaskets and seals shall be of materials suitable for the intended service.

5.5 The pressure ratings established under this specification are based on materials of high quality produced under regular control of chemical and mechanical properties by a recognized process. The manufacturer shall be prepared to submit a certificate of compliance verifying that his product has been so produced and that it has been manufactured from material whose chemical and mechanical properties are at least equal to the requirements of the appropriate specification.

5.6 For materials not having values of allowable stress tabulated in Section VIII, Division 1 of the ASME Code, allowable stresses shall be determined in accordance with the procedures outlined in Subsection C and Appendix P of that section. Where it can be shown that the values of allowable stress listed for a particular material in one product form (because of similar chemistry, physical properties, heat treatment, and so forth) are applicable to the same material in an unlisted product form, the listed values of allowable stress may be used.

5.7 Cast iron shall be limited to services below 450°F (232°C). Cast iron fittings conforming to B16.1 and B16.4 are limited to Class 125 and 250.

5.8 Users are cautioned to exercise care in the selection of materials, as some fluids may react chemically with some materials used in these products.

6. Other Requirements

6.1 The maximum allowable working pressure (MAWP) of fluid conditioner fittings covered under this specification shall be established by at least one of the following methods:

6.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII, Division 1 of the ASME Code. If burst-type tests as outlined in paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of B to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture.

6.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1 of the ASME Code.

6.2 Where welded construction is used, weld joint design details shall be in accordance with Section VIII, Division 1 of the ASME Code except as noted in 6.3. Supplemental radiography requirements are presented in 7.3. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code. Except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.

6.3 Welds on fluid conditioner fittings greater than 6-in. (152-mm) internal diameter or 1.5-ft³ (0.042-m³) net internal volume and rated above 600 psi (4.14 MPa) or 400°F (204°C) shall be of the following types as listed in Table UW-12 of the ASME Code: Type (1) for Category A joints; Types (1) or (2) for Category B joints; and all Category C and D joints shall be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall. Welded joint categories are defined under UW-3 of the ASME Code.

6.4 Post-weld heat treatment shall be in accordance with Section VIII, Division 1, except that fluid conditioner fittings greater than 6-in. (152-mm) internal diameter or 1.5-ft³ (0.042-m³) net internal volume, rated above 600 psi (4.14 MPa) or 400°F (204°C), and fabricated of carbon or low alloy steel, shall be post-weld, heat-treated regardless of thickness.

6.5 Inlet and outlet connections consisting of welded flange end fittings shall be in accordance with Specification F 722. Pipe end connections for fluid conditioner fittings shall be in accordance with one of the specifications listed in 2.2 or 2.3. Where radiography is required by 7.3.2, all welded inlet and outlet connections shall be butt-weld joints as required by Specification F 722 for Class 1 piping systems. Threaded inlet and outlet connections shall be in accordance with 6.6.

6.6 Threaded pipe connections shall be limited to the following services:

| NPS ¼ in. (20 mm) and below . . . 1500 psig (10.3 MPa) max |
| NPS 1 in. (25 mm) and below . . . 1200 psig (8.27 MPa) max |
| NPS 2 in. (50 mm) and below . . . 600 psig (4.14 MPa) max |
| NPS 3 in. (80 mm) and below . . . 400 psig (2.76 MPa) max |

6.7 Threaded pipe joints above nominal pipe size (NPS) 2 (50 mm) shall not be used in systems that require radiographic examination in 7.3.2.

6.8 For multiplex fluid conditioner fittings:

6.8.1 Piping and valves shall be in accordance with ANSI B31.1. Welded joints used in the interconnected piping shall be in accordance with Specification F 722 for equivalent class of pipe.
6.8.2 The maximum valve seat leakage shall not be greater than that allowed by MSS SP-61 or SP-67.

6.8.3 There shall be continuous fluid flow during changeover of the elements.

6.9 For a fluid conditioner fitting requiring cleaning or servicing, its construction shall facilitate cleaning and minimize fluid spillage.

6.10 All performance ratings assigned to a fluid conditioner fitting shall be confirmed by calculations or testing (see 7.4), or both, and certified by the manufacturer.

6.11 If an external protective device is required for the fluid conditioner fitting to pass the fire test in 7.2, the device shall sufficiently encase the fluid conditioner fitting to protect the fitting from a fire when it is installed in its normal position(s).

7. Test Methods

7.1 All fluid conditioner fittings shall be pressure tested by one of the following methods:

7.1.1 Conduct a hydrostatic test at 1 1/2 times the 100°F (37°C) rated MAWP of the fluid conditioner fitting. Perform the test with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 15 s for fluid conditioner fittings less than NPS 2 (50 mm), 1 min for fluid conditioner fittings NPS 2 1/2 (63 mm) through 8 (203 mm), and 3 min for larger sizes. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

7.1.2 Class II fluid conditioner fittings of NPS 2 (50 mm) and smaller with other than flanged connections may, at the option of the manufacturer, be air tested to the lesser of 1.2 times the MAWP or 80 psig (0.55 MPa). The minimum duration of the test shall be 15 s. Visually detectable leakage is not acceptable.

7.1.2.1 Manufacturers exercising this option shall also certify that a prototype from each production lot of the same size fluid conditioner fitting was subjected to a hydrostatic test in accordance with 7.1.1.

7.2 Test a prototype of a fluid conditioner fitting design that requires a fire test in accordance with 5.2 as follows:

7.2.1 Position the fluid conditioner fitting 9 in. (230 mm) above the top edge of an open pan of heptane large enough to engulf the fluid conditioner fitting completely in the fire. The pan shall conform to the following minimum dimensions:

7.2.1.1 Depth, 1 1/2 in. (38 mm).

7.2.1.2 Width, twice the width of the fluid conditioner fitting but no less than 8 1/2 in. (220 mm).

7.2.1.3 Length, twice the length of the fluid conditioner fitting but no less than 14 in. (360 mm).

7.2.2 Add to the pan sufficient heptane to provide for a 2 1/2-min burn.

7.2.3 Mount thermocouples so as to sense the flame temperature in the same plane and elevation as the fluid conditioner fitting assembly. Pressurize with water the fluid conditioner fitting to its MAWP during the burning portion of the test. Following ignition of the heptane, begin timing and monitor the temperature. The temperature shall reach a minimum of 1200°F (649°C) but shall not exceed 1350°F (732°C). If 1200°F (649°C) is not reached, repeat the test using a new specimen. If 1350°F (732°C) is exceeded, discard the results and repeat the test.

7.2.4 At the end of the 2 1/2-min of fire exposure, extinguish the flame, relieve the pressure, and allow the water to flow through the assembly. With free flow established, pressurize the fluid conditioner fitting to its MAWP and hold for 30 s. Failure to establish a free flow, or any fluid leakage during fire exposure or the subsequent pressure test, shall constitute failure.

7.2.5 Mount in their normally installed position those fluid conditioner fittings that require external protective devices installed to pass the above fire test. Test in each position those fluid conditioner fittings that can be mounted in more than one position. A different fluid conditioner fitting may be used for each test. If it is possible for this protection to be separated from the fluid conditioner fitting body by purchasers or users, mark the body to indicate that this protection is required (see 9.2).

7.2.6 Test only the smallest and largest sizes of a particular fluid conditioner fitting design to certify the design as having passed the above fire test.

NOTE 1—Manufacturers are cautioned that the application of this test can be hazardous. It is recommended that it be performed by a qualified laboratory familiar with the conduct of this type test.

7.3 Inspect all welds as follows:

7.3.1 Visually examine all welds in accordance with ANSI B31.1.

7.3.2 Welded inlet and outlet connections of Class I fluid conditioner fittings, equal to or greater than 4-in. (100-mm) nominal diameter or 0.375-in. (9.5-mm) nominal wall thickness, shall be 100% radiographically examined in accordance with UW-51 of the ASME Code.

7.3.3 For Class I multiplex fluid conditioner fittings, all butt-welds in interconnected piping greater than 4-in. (100-mm) nominal diameter or 0.375-in. (9.5-mm) nominal wall thickness shall be 100% radiographically examined in accordance with UW-51 of the ASME Code.

7.3.4 Fluid conditioner fittings greater than 6-in. (152-mm) internal diameter or 1.5-ft 3 (0.042-m 3 ) net internal volume and rated above 600 psi (4.14 MPa) or 400°F (204°C) shall have all butt-welds fully radiographed in accordance with UW-51 of the ASME Code.

7.4 A prototype of each fluid conditioner fitting having designated performance ratings not confirmed by calculations shall be tested to verify the ratings. The test shall be of the manufacturer’s specification practice and shall be suitable for the type, size, and capacity of the fluid conditioner fitting.

7.4.1 Test only that combination of sizes, capacities, and so forth, of a particular fluid conditioner fitting design to certify the ratings of a complete family of a fluid conditioner fitting of the design.

8. Certification

8.1 When specified in the purchase order or contract, the manufacturer’s certification shall be furnished to the purchaser stating that samples representing each lot or prototypes have been manufactured, tested, and inspected in accordance with
this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

9. Product Marking

9.1 Each fluid conditioner fitting shall have a securely attached name plate or other permanent marking indicating the following:

  9.1.1 Manufacturer’s name or trademark.
  9.1.2 Maximum allowable working pressure and temperature as designed and tested (for example, 150 psi at 150°F).
  9.1.3 Size (end connection NPS).
  9.1.4 ASTM designation number of this specification.
  9.1.5 Direction of flow (by an arrow or the word “inlet,” “outlet,” or both).

  9.1.6 If radiographed in accordance with 7.3, an “X” shall be placed after the ASTM designation number.

  9.2 If a removable protective device is installed to pass the fire test of 7.2.5, an “S” shall be placed after the ASTM designation number.

10. Quality Assurance

10.1 The fluid conditioner fitting manufacturer shall maintain the quality of the fluid conditioner fittings that are designed, tested, and marked in accordance with this specification. At no time shall a fluid conditioner fitting be sold indicating that it meets the requirements of this specification if it does not meet the requirements herein.

11. Keywords

11.1 fluid conditioner fittings; piping applications; pressure-retaining components
Standard Specification for Electrical Insulation Monitors for Monitoring Ground Resistance in Active Electrical Systems [Metric]\(^1\)

This standard is issued under the fixed designation F 1207M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers electrical insulation monitoring devices, intended as permanently installed units, for use in the detection of ohmic insulation faults to ground in active, ac ungrounded electrical systems.

1.2 Limitations—This specification does not cover devices which are not intended for operation for: dc ungrounded systems or ac ungrounded systems with dc components unless ac to dc conversion is isolated from the monitored system with transformers.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 9, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 UL Standard:
UL 1053 Ground-Fault Sensing and Relaying Equipment\(^2\)

3. Terminology

3.1 Definitions:

3.1.1 ac internal resistance—a monitor’s impedance between the measuring terminals and ground terminals.

3.1.2 ac ungrounded electrical system—a monitored system that has no intentional connection from phase or neutral to ground and can continue to perform normally if one conductor becomes connected to ground.

3.1.3 dc internal resistance—a monitor’s ohmic resistance between the measuring and ground terminals.

3.1.4 input voltage—the supply voltage at the terminals of an insulation monitor.

3.1.5 measuring voltage—the output dc voltage from the insulation monitor that is superimposed between the ac ungrounded system and ground.

3.1.6 nominal contact voltage—the voltage rating for a monitor’s internal relay contacts.

3.1.7 nominal frequency—the frequency of a monitored system.

3.1.8 nominal voltage—the voltage (phase-to-phase) of a monitored system.

3.1.9 response value—the adjustable or preset set point value of system insulation resistance for which an insulation monitor will provide alarm indication.

3.1.10 system insulation resistance—the total insulation resistance to ground to be monitored which is measured by dc voltage.

4. Monitor Classification

4.1 Type 1—Insulation monitor for 115-V, 3-phase or single-phase, 60-Hz, ac ungrounded electrical systems.

4.2 Type 2—Insulation monitor for 115-V, 3-phase or single-phase, 400-Hz, ac ungrounded systems.

4.3 Type 3—Insulation monitor for 440-V, 3-phase or single-phase, 60-Hz, ac ungrounded systems.

4.4 Type 4—Insulation monitor for 440-V, 3-phase or single-phase, 400-Hz, ac ungrounded systems.

4.5 Type 5—Insulation monitor for up to 1000-V, 3-phase or single-phase, 50 to 400-Hz, ac ungrounded systems.

\(^1\) This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.

\(^2\) Available from Underwriters Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.
5. Ordering Information

5.1 Monitoring devices shall be ordered by specifying the following information:
   5.1.1 Nominal voltage and frequency.
   5.1.2 Response value/set point range in kilohm.
   5.1.3 Special options, that is, test buttons, ohmmeters, visual indicators, and so forth.

6. Requirements

6.1 The measuring voltage shall not increase more than 10 % when the monitor is supplied with 110 % of the input voltage.
6.2 The monitor shall be capable of both continuous and on-demand operation.
6.3 The monitor shall have provisions for an external (remote) audible or visual alarm to operate when the resistance value falls below the response value or a remote indication of the insulation value of the ac ungrounded system in kilohms, or both.
6.4 The ac internal resistance shall be at least 250-Ω/V nominal voltage. The minimum resistance shall not be less than 15 kΩ.
6.5 The dc internal resistance shall be at least 30-Ω/V nominal voltage and shall limit the measuring dc output current from exceeding 12 mA.
6.6 The monitor’s response tolerance shall not exceed ±5 % of the set point value at room temperature (25 ± 5°C (72 ± 9°F)) and rated input voltage.
6.7 When specified, insulation monitors shall be furnished with adjustable response values and designed to preclude tampering or unauthorized changes.
6.8 The insulation monitor shall reliably function in an ambient temperature range from 0 to 50°C (32 to 122°F). Storage temperatures of −20 to +60°C (−4 to 140°F) must not damage the insulation monitors.
6.9 Insulation monitors shall include a built-in test device or be equipped with connection provisions for a test device to be furnished with the equipment which can verify the monitor’s proper functioning. If the monitor is equipped with a built-in test device, the value of the test resistor shall be marked on the monitor.
6.10 Insulation monitors shall include an integral visual indicator or external connection provisions for external annunciation of the monitor’s set-point response.
6.11 If the insulation monitor includes an ohmmeter for the insulation resistance indication, the meter’s tolerance (actual rather than indicated values) shall not exceed ±5 % for:
   6.11.1 An insulation monitor with one preset response value at this value.
   6.11.2 An insulation monitor with adjustable response value at the midpoint of the adjustment range.
   6.11.3 Conditions of room temperature (as specified in 6.6) and rated input voltage.
6.12 Built-in relays for connection to external alarms shall have a switching capacity of at least 2 A at 250-V ac or 0.5 A at 120-V dc.
6.13 Between isolated, outgoing circuits and between these circuits and extraneous conductive parts, insulation monitors shall have creepage and air gap separation in accordance with UL 1053 for voltages up to 300 V. For higher nominal voltages, see IEC Report 664.

7. Product Marking

7.1 The following data shall be identified on an insulation monitor’s enclosure:
   7.1.1 Name of manufacturer.
   7.1.2 Type of monitor.
   7.1.3 Connection diagram.
   7.1.4 Nominal voltage rating.
   7.1.5 Input voltage.
   7.1.6 Nominal frequency.
   7.1.7 Response value or range.
   7.1.8 Test resistance value in accordance with 6.9.
   7.1.9 Serial number, or year of production.


8.1 The manufacturer’s equipment manual shall provide the following information in addition to that required in 7.1:
   8.1.1 Description of operation.
   8.1.2 Values for ac and dc internal resistance.
   8.1.3 Connection diagram.
   8.1.4 Nominal value of dc measuring voltage, based on possible supply voltages.
   8.1.5 Maximum dc measurement current at short-circuit conditions.
   8.1.6 Nominal contact voltage and current ratings for integral relays in accordance with 6.12.
   8.1.7 A note advising that external dc voltage applied to the monitor’s measuring terminals may falsify the indication or destroy the insulation monitor.
   8.1.8 Magnitude of external dc voltages, independent of their polarity, which may continuously be applied to the insulation monitor without damaging it.

9. Test Methods

9.1 Type Test—Perform type testing of insulation monitors to confirm that the response tolerances stipulated are not exceeded and that the requirements of Section 6 are met. A newly developed monitor shall be in complete compliance with the following:
   9.1.1 The measuring devices used for testing shall enable a slow stepless or step-by-step alteration of the simulated insulation resistance. On testing, the resistance shall be decreased slowly and the insulation monitor’s response shall be observed.
   9.1.2 Voltage measurements shall be taken to confirm that the requirements of 6.1 and 8.1.4 are met. The voltmeter’s internal resistance shall have a minimum value not less than 100 times the dc internal resistance of the measuring circuit.
   9.1.3 The ac internal resistance specified in 6.4 shall be verified with an rms milliampmeter and a power supply having

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an output rated at nominal voltage and nominal frequency, an internal resistance of under 10 Ω, and a harmonic distortion of less than 5 %. The rms milliammeter shall be connected between the monitor’s measuring terminal(s) and output terminal of the power supply. The other output terminal of the power supply shall be connected to the monitor’s ground terminal. The monitor’s internal impedance, χ, shall be calculated as follows:

\[
χ = \frac{\text{nominal voltage}}{\text{ac rms current}}
\]

9.1.4 When insulation monitors have steplessly adjustable response values, test at least five points within the marked adjustment range in order to verify the requirements of 6.6. For this purpose, test the ranges’ starting and final points and uniformly distributed points within the range.

9.2 Production Test—The production test proves the correct quality and functioning of new monitors. Each insulation monitor shall be subjected to these tests.

9.2.1 Visually examine each monitor to verify appropriate markings as specified in Section 7.

9.2.2 Perform routine tests at room temperature (25 ± 5°C (72 ± 9°F)) with rated input voltage and by a measuring device complying with the requirements of 9.1.1.

9.2.3 When the insulation monitors have a steplessly adjustable response value, test the response at the range’s starting and final points.

9.2.4 Perform a voltage withstand test on the monitor to verify that the monitor is able to withstand an ac test voltage equal to twice the nominal voltage plus 1000 V for a period of 1 s without any breakdown or flashover. Perform the tests as follows:

9.2.4.1 Bridge all primary terminals.
9.2.4.2 Bridge all electronic terminals.
9.2.4.3 Bridge all relay contacts.
9.2.4.4 Apply the test potential as follows: (a) between bridged primary terminals and bridged electronic terminals; (b) between bridged primary terminals and bridged relay contacts; and (c) between bridged electronic terminals and bridged relay contacts.
9.2.4.5 Connect all bridged circuits together.
9.2.4.6 Apply test potential between the connected, bridged circuits and all dead metal parts that may become live (for example, enclosures).
9.2.5 Verify that the built-in test device is properly functioning.
9.2.6 If indicating instruments are built into the insulation monitor, verify that these instruments do not exceed the response tolerances specified in 6.11.

10. Keywords

10.1 active ac electrical system; electrical; electrical insulation; electrical insulation monitor; ohmic insulation faults; shipboard; ungrounded electrical systems
Standard Specification for Berths, Marine

This standard is issued under the fixed designation F 1244; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the construction of marine berths for officers, crew, and passengers.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
   A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled
   A 512 Specification for Cold-Drawn Butt weld Carbon Steel Mechanical Tubing
   F 825 Specification for Drawers, Furniture, Marine, Steel
   F 1085 Specification for Mattress and Box Springs, Berths

2.2 American Institute of Steel Construction Manual:
   AISC Wire and Sheet Metal Gages-Equivalent Thicknesses in Decimals of an Inch, U.S. Standard Gage for Uncoated, Hot and Cold Rolled Sheets

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 base— the structure on which the drawer and pan sections are supported and which serves to tie the berth to the deck.

3.1.2 berth—an item of fixed or built-in furniture for sleeping, with a base and drawer section below the mattress and box spring pan.

3.1.3 berth side rail—the berth side that runs from head to foot of berth.

3.1.4 box spring—the resilient box-type support for the mattress covered by fabric.

3.1.5 drawer section—the section of the berth below the pan section normally designed to contain drawers for stowage of life preservers and other items.

3.1.6 hand—the berth may be right hand, left hand, or finished both sides for use in the middle of the room. Right hand is defined as follows: the berth is right hand if the head of the berth is on the right hand end when the berth is viewed from the front. Left hand is opposite. See Fig. 1 and Fig. 2 and Table 1 and Table 2 for elevations of left-handed berths. A berth finished on both sides is not shown, but it is one that is accessible from either side, has the head of the berth against a bulkhead, and is not handed.

3.1.7 lee rail—a guard to inhibit a person from rolling out of bed because of ship motion. In this specification, the lee rail is a raised pine railing.

3.1.8 mattress—a fabric-covered, box-type unit containing springs and cushioning material that supports the sleeping surface.

3.1.9 pan section—the section of the berth designed to support the mattress and box spring.

4. Classification

4.1 Type I—A single berth with pipe, side lee rail with a box spring and mattress pan having inside measurements of 54 in. (1372 mm) wide by 80 1/2 in. (2045 mm) long. (See Fig. 1, Table 1, and Note 8 and Note 11 of Fig. 1.)

4.1.1 Type IA—Berths conforming generally to the Type I specifications but having special requirements as indicated in the ordering information.

4.2 Type II—A single berth with pipe, side lee rail with a box spring and mattress pan having inside measurements of 39 in. (991 mm) wide by 80 1/2 in. (2045 mm) long. (See Fig. 1, Table 1, and Note 8 and Note 11 of Fig. 1.)

4.2.1 Type IIA—Berths conforming generally to the Type II specifications but having special requirements as indicated in the ordering information.

4.3 Type III—A two-high berth with pipe, side lee rail, the same as Type II, but fitted with an additional pan and uprights to form an upper berth. (See Fig. 2, Table 2, and Note 8, Note 10, and Note 11 of Fig. 1.)

4.3.1 Type IIIA—Berths conforming generally to the Type III specifications but having special requirements as indicated in the ordering information.
5. Ordering Information

5.1 Orders for items purchased under this specification shall include the following:

5.1.1 Type of berth.
5.1.1.1 Type I, IA; II, IIA; or III, IIIA.
5.1.1.2 Hand—Right, left, or finished both sides.
5.1.2 Quantity—The quantity of right hand, left hand, or finished both sides for each type.
5.1.3 Mattress and Box Spring—Shall be furnished in accordance with Specification F 1085.

5.1.4 Paint:

5.1.4.1 Color—The purchaser shall pick from manufacturer’s samples or submit a sample chip of the color desired.
5.1.4.2 The manufacturer’s standard baked enamel will be furnished unless otherwise required and specified by the purchaser.

5.1.5 Weights—If the total weight of the berth assembly is required, it shall be requested by the purchaser.

5.1.6 Options:

5.1.6.1 If a special architectural appearance or finish is required for these berths to match other furniture in the same space, it shall be defined in the ordering documents.
5.1.6.2 The pipe lee rail at the foot of all berths shall be furnished extending above the mattress, to restrain occupants in heavy sea.
5.1.6.3 Normally, on berths installed in a corner, the head of the berth is installed against one of the bulkheads. On some smaller ships, the trim of the vessel is such that this configuration would place the foot of the berth higher than the head. In such cases, the head and foot shall be reversed, and this requirement shall be so noted in the ordering document.

6. Materials and Manufacture

6.1 For berth details, see Fig. 1 and Fig. 2 and Table 1 and Table 2.

6.2 Sheet Metal:

6.2.1 Sheet metal shall be steel in accordance with Specification A 366/A 366M.
6.2.2 Minimum steel sheet metal thicknesses shall be as follows:
6.2.2.1 Drawer section 18 USSG (0.0478 in. or 1.21 mm).
6.2.2.2 Pan section 18 USSG (0.0478 in. or 1.21 mm).
6.2.2.3 Base frame 16 USSG (0.0598 in. or 1.52 mm).

6.3 Welding:

6.3.1 Metal components shall be joined by welding.
6.3.2 Welding shall be adequate to prevent racking of berth components during handling.
6.3.3 Spotwelds shall be spaced approximately 3 to 5 in. (76 to 127 mm) on centers.
6.3.4 Spotwelds, on exposed surfaces, higher than the general surface of the adjacent metal, shall be ground flush.
6.3.5 Spotweld depressions, on exposed surfaces, shall be spot filled and sanded.
6.4 Side and end panels shall be suitably stiffened to prevent buckling or oil-canning.
6.5 Sound deadening shall be vermin proof and applied to unstiffened areas where needed, and in thickness required, to sound deaden berth.
6.6 Drawers shall be manufactured in accordance with Specification F 825. Minimum stowage capacity for each drawer shall be 1.35 ft³ (0.038 m³).
6.7 A furniture base shall be provided suitable for securing berth to deck. Base shall be equipped with means for leveling when installed aboard ship.
6.8 The mattress and box spring shall be manufactured in accordance with Specification F 1085. Mattress and box spring sizes shall be as specified in Table 3.

6.9 Berths may be made in sections: base, drawer section, and berth pan. At the option of the furniture manufacturer, the berth pan section may be furnished as an integral part of the drawer section or as a separate unit. The base shall be suitable for securing to the deck. The other sections shall be attached to the base and to each other so as to form a unit that is adequately

**TABLE 1 Dimensions of Type I and Type II Berths**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Dimension</th>
<th>Tolerance to + or −</th>
<th>Dimension</th>
<th>Tolerance to + or −</th>
<th>Note (See Fig. 1)</th>
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</thead>
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<tr>
<td>Length</td>
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<td>max</td>
<td>2159</td>
<td>max</td>
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<tr>
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<td>max</td>
<td>1499</td>
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<tr>
<td>Type II width</td>
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<td>44</td>
<td>max</td>
<td>1118</td>
<td>max</td>
</tr>
<tr>
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<td>min</td>
<td>762</td>
<td>min</td>
</tr>
<tr>
<td>Lee rail length</td>
<td>D</td>
<td>24</td>
<td>min</td>
<td>610</td>
<td>min</td>
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<tr>
<td>Toe space height</td>
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<td></td>
<td>121</td>
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<tr>
<td>Drawer section height</td>
<td>F</td>
<td>6⅔</td>
<td>⅔</td>
<td>165</td>
<td>3</td>
</tr>
<tr>
<td>Deck to mattress</td>
<td>G</td>
<td>24⅔</td>
<td></td>
<td>629</td>
<td></td>
</tr>
<tr>
<td>Box spring plus mattress</td>
<td>H</td>
<td>13⅔</td>
<td></td>
<td>343</td>
<td></td>
</tr>
<tr>
<td>Lee rail height</td>
<td>J</td>
<td>6⅔</td>
<td></td>
<td>165</td>
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<tr>
<td>Toe space, front</td>
<td>L</td>
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<td>min</td>
<td>38</td>
<td>min</td>
</tr>
<tr>
<td>Toe space, end</td>
<td>M</td>
<td>⅓</td>
<td></td>
<td>6</td>
<td>min</td>
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<td>Type I mattress or box spring width</td>
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<tr>
<td>Type II mattress or box spring width</td>
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<td></td>
<td>965</td>
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<tr>
<td>Mattress or box spring length</td>
<td>O</td>
<td>79⅔</td>
<td></td>
<td>2019</td>
<td></td>
</tr>
<tr>
<td>Mattress or box spring thickness</td>
<td>P</td>
<td>7</td>
<td></td>
<td>178</td>
<td></td>
</tr>
</tbody>
</table>
secured and capable of resisting motions of the vessel. Berths shall have backs suitable for securing to bulkheads.

6.10 The drawer for stowing life preservers shall be identified by the words “life preserver” in letters 1/4 in. (6.4 mm) high on the face of the drawer.

6.11 Berths supplied in accordance with this specification will use pipe, side lee rails.

6.12 Pipe lee rail shall be 1-in. (25.4-mm) outside diameter by 0.065-in. (1.65-mm) cold-drawn buttweld carbon steel tubing per Specification A 512. Equal strength pipe rail of aluminum or other metals in appropriate finishes can be supplied, if so specified in the ordering documents.

7. Performance Requirements

7.1 The completed berth assembly with drawers installed, but without a mattress or box spring, shall satisfy the corresponding performance requirements of the following:

7.1.1 Specification F 825.

7.1.2 The berths, without mattress or box springs, shall be capable of supporting a minimum vertical load of 500 lb (4.90 kN) applied uniformly over the entire sleeping surface or a single 250-lb (2.45-kN) vertical load applied over a 1-ft² (0.093-m²) area anywhere on the berth, without causing permanent deformations.
8. Dimensions

8.1 For dimensions, see Table 1 and Table 2.

9. Workmanship, Finish, and Quality Assurance

9.1 All workmanship and material shall be of specified quality in keeping with the best commercial marine practice so as to produce each item suitable for its intended use.
9.2 All exposed burrs and raw or sharp edges that might be injurious to personnel or damage linens shall be removed.
9.3 Depressions considered unacceptable for the product’s end use shall be spot filled and sanded smooth.
9.4 All steel surfaces, unless corrosion resistant or with a corrosion resistant plating, shall be painted so as to prevent corrosion.

10. Inspection and Certification

10.1 The manufacturer shall inspect and certify that the item of furniture complies with this furniture specification and the loading requirements as defined in Section 7.

11. Packaging and Package Marking

11.1 Each item shall be marked in accordance with the purchase order.
11.2 Packaging shall be provided and shall be acceptable to a common carrier.

12. Keywords

12.1 berth; box spring; lee rail; marine; marine berth; mattress; ship
1. Scope

1.1 This specification covers single- and double-compression and self-closing faucets for shipboard plumbing installations.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the test methods portion, Section 10, of this standard. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
B 62 Specification for Composition Bronze or Ounce Metal Castings
B 584 Specification for Copper Alloy Sand Castings for General Applications

2.2 American National Standards Institute Standard: B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)

2.3 Federal Specifications:
PPP-B-566 Boxes, Folding, Paperboard
PPP-B-585 Boxes, Wood, Wirebound
PPP-B-591 Boxes, Shipping, Fiberglass, Wood-Cleated
PPP-B-601 Boxes, Wood, Cleated-Plywood
PPP-B-621 Boxes, Wood, Nailed and Lock-Corner
PPP-B-636 Box, Shipping, Fiberglass
PPP-B-676 Boxes, Setup
QQ-N-290 Nickel Plating (Electrodeposited)
QQ-C-320 Chromium Plating (Electrodeposited)

2.4 Military Specification:
MIL-P-116 Preservation, Methods of
MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129 Marking for Shipment and Storage

2.5 Military Standards:
MIL-STD-162 Naval Sea Systems Command (NAVSEA): NAVSEA Drawing 803-5959206 Faucet, Metering
NAVSEA Drawing 805-1623970 Unit, Lavatory for Officers Station

3. Classification

3.1 Faucets shall be of the following types and classes as specified (see 4.1):

3.1.1 Type I—Standard (bibb):
3.1.1.1 Class A—Compression, plain end.
3.1.1.2 Class B—Compression, hose end.
3.1.1.3 Class C—Self-closing.

3.1.2 Type II—Lavatory, self-closing, low spout:
3.1.2.1 Class A—Fast-closing.
3.1.2.2 Class B—Slow-closing, depression type.

3.1.3 Type III—Folding lavatory, self-closing.

3.1.4 Type IV—Elbow operated.

3.1.5 Type V—Lavatory, combination water supply and drain fixture.

3.1.6 Type VI—Combination supply fixture swing spout for use on galley sinks.

3.1.7 Type VII—Single supply fixture swing spout for use with steam kettles and urns.

3.1.8 Type VIII—Supply fixture for pressed metal and shock mounted china lavatories.

3.1.9 Type IX—Lavatory, combination water supply and drain fixtures, depression type.

4. Ordering Information

4.1 Orders for equipment under this specification shall include the following information, as required, to describe the equipment adequately:

4.1.1 ASTM designation and year of issue,
4.1.2 Type and class of faucet required (see 3.1),
4.1.3 Type of handle required (see 6.11),
4.1.4 Marking required for handles (see 13.1),
4.1.5 Size and weight of Type I faucet required (see 7.1),
4.1.6 Overall dimensions for Type II faucets (see 7.2),
4.1.7 Shank design for Type II, Class B faucets (see 6.2.3.2),
4.1.8 Overall dimensions and position of inlet (side or bottom) for Type III faucets (see 7.3),
4.1.9 Overall dimensions and whether spray is required for Type IV faucets (see 6.4.1.3 and 7.4),
4.1.10 Length of spout for Type VI fixtures (see 7.6.1),
4.1.11 Whether escutcheon plates are provided for Type VI faucets (see 6.6.3),
4.1.12 Whether connections are other than ¼-in. nominal pipe size (NPS) (see 6.8.2.1),
4.1.13 Sample size for examination and testing (see 10.1, 10.2, and 11.1), and
4.1.14 Optional requirements, if any (see Supplementary Requirements S1 through S3).

5. Materials
5.1 Faucet bodies shall be made of bronze conforming to Specification B 62 or Specification B 584.
5.2 Handles shall be of commercial grade cast or forged brass or bronze.
5.3 Bonnets, handwheels, and nuts shall be of commercial quality brass or bronze; machine screws shall be made of commercial brass.
5.4 Seat washers shall be of a rubber or fiber material capable of withstanding the hydrostatic test of 10.1 and suitable for water temperature from 30 to 190°F (−1 to 88°C) without deterioration of material.
5.5 Springs for self-closing faucets shall be of corrosion-resistant steel, phosphor bronze, or nickel copper.

6. Requirements
6.1 Type I, standard.
6.1.1 Type I faucets shall be in accordance with Fig. 1.
6.1.1.1 Faucets shall have hexagon shoulders and a male threaded inlet.
6.1.2 Class A faucets shall be plain; Class B shall have ¼-in. (19-mm) hose thread. Class C shall be the same as Class A except they shall be self-closing.
6.2 Type II, lavatory, self-closing, low spout.
6.2.1 Faucets shall be provided with a shank, fitted with a metal washer and locknut and with a ¼-in. NPS tailpiece.
6.2.1.1 The shank of the faucet and one end of the tailpiece shall be arranged as a ground joint union; the other end of the tailpiece shall be provided with outside threads ¼-in. NPS.
6.2.2 Class A lavatory faucets shall be in accordance with Fig. 2.
6.2.2.1 They shall operate on a cam, ball, or roller bearings.
6.2.2.2 Faucets with renewable operating units may be used.
6.2.3 Class B lavatory faucets shall be in accordance with Fig. 3.
6.2.3.1 They shall be fitted with an adjusting device, which cannot be tampered with, for regulating the closing from 3 to 20 s in accordance with NAVSEA Drawing 803-5959206.
6.2.3.2 Shank design shall be as specified (see 4.1.7).
6.3 Type III, folding lavatory self-closing.
6.3.1 Faucets shall be in accordance with Fig. 4.
6.3.1.1 They shall be of the cam, ball or roller bearing type.
6.3.1.2 The body shall be designed for back mounting.
6.4 Type IV, elbow operated.
6.4.1 Faucets shall be in accordance with Fig. 5 except that a gooseneck spout is acceptable.
6.4.1.1 They shall have a double faucet with a rigid spout with or without buttons, renewable seats, and sleeves or renewable units and integral stops in shanks with union inlets.
6.4.1.2 Escutcheon plates shall be provided for the fixtures.
6.4.1.3 Spray shall be provided when specified (see 4.1.9).
6.5 Type V, lavatory, combination water supply and drain fixtures.
6.5.1 Fixtures shall be in accordance with Fig. 6.
6.5.1.1 The trunion lugs shall be designed so that the trunions will be held in place by spring clips or other device.
6.6 Type VI, combination supply fixture swing spout for use on galley sinks.
6.6.1 Fixtures shall be in accordance with Fig. 7.

6.6.2 Fixtures shall have manifolded hot and cold compression type faucets, discharging through a common swing spout.

6.6.2.1 The swing joint shall be of rugged design and packed with material resistant to water and leakage at temperatures of 30 to 200°F (−1 to 93°F).

6.6.3 The faucets shall have renewable seats, sleeves, or renewable units and steps in the body and shanks with union inlet connection, with or without escutcheon plates as specified (see 4.1.11).

6.7 Type VII, single-supply fixture swing spouts for use with steam kettles and urns.

6.7.1 Fixtures shall be in accordance with Fig. 8.

6.7.1.1 They shall consist of a single-globe-type valve with NPS threaded inlet and outlet and an adaptor designed to receive a swing spout.

6.7.1.2 The swing joint shall be ruggedly constructed and fitted with packing material resistant to leakage and water at temperatures of 30 to 200°F (−1 to 93°C).
6.7.2 Class A or B spouts may be of cast or extruded construction.
6.7.3 Class A or B spouts shall be designed for installation on the valve.
6.8 Type VIII, supply fixture for pressed metal and shock mounted china, lavatories.
6.8.1 Fixtures shall be in accordance with Fig. 9.
6.8.2 Fixtures shall consist of a manifold incorporating hot and cold water NPS female threaded inlet connections to permit connection from top or bottom of the manifold and common outlet (through direct compression type or inverted compression type) faucets.
6.8.2.1 Unless otherwise specified (see 4.1.12), the connections shall be ½-in. NPS.
6.8.3 Faucets shall be of the self-closing type operating on a cam, ball, or roller bearing.
6.8.4 The faucet may seat with or against the water supply pressure.
6.8.5 Faucets with renewable operating units will be acceptable.
6.9 Type IX, lavatory, combination water supply and drain fixtures, depression type.
6.9.1 In addition to the requirements specified herein, Type IX fixtures shall also be in accordance with NAVSEA Drawing 803-5959206.
6.10 Threads for threaded parts shall conform to the applicable requirements of ANSI B1.1.
6.11 Handles shall be four-ball, four-arm, star, T, loose-key T, or lever type, as specified (see 4.1.3), with the exception noted in 6.11.1.
6.11.1 Handles for Type II, Class B and Type IX faucets shall be in accordance with NAVSEA Drawing 803-5959206.
6.11.2 Handwheels may be provided for Type VII faucets.

7. Dimensions, Mass, and Permissible Variations
7.1 Type I faucets shall be of the sizes and weights specified in Table 1.
7.2 Type II faucets shall be of the dimensions specified in 4.1.6.
7.2.1 Dimensions shown on Fig. 3 are approximate.
7.2.2 Faucets shall have a minimum weight, including the tailpiece, of 1.5 lb (0.7 kg) ± 5%.
7.3 For Type III faucets, overall dimensions and position of the inlet (side or bottom) shall be as specified (see 4.1.8). The dimensions shown on Fig. 4 are approximate.
7.4 For Type IV faucets, overall dimensions shall be as specified (see 4.1.9). The dimensions shown on Fig. 5 are approximate.
7.5 Type V fixtures shall conform to the dimensions shown on Fig. 6.
7.6 Type VI fixtures shall conform to the dimensions shown on Fig. 7.
7.6.1 The swing spout shall be 8- or 14-in. (203- to 356-mm) minimum length, as specified (see 4.1.10).
7.7 Type VII fixtures shall conform to the dimensions shown on Fig. 8.
7.8 Type VIII fixtures shall conform to the dimensions shown on Fig. 9.
7.9 Type IX fixtures shall conform to the dimensions shown on NAVSEA Drawing 803-5959206.

8. Workmanship, Finish, and Appearance
8.1 Faucets shall be true to form and free from all defects or blemishes affecting the appearance or serviceability.
8.2 Before plating, faucets shall be thoroughly cleaned of sand and scale by the acid-bath process (or a process satisfactory to the purchaser) and shall have all fins and roughness removed and polished.
8.3 Nickel chromium plating shall be applied to surfaces normally visible after installation including exposed bolts, nuts, screws, or other fastenings.
8.3.1 Nickel plating on copper-base alloys shall be Class 1, Type VII (QC) in accordance with QQ-N-290.
8.3.2 Chromium plating, over nickel, shall be Class 1, Type I in accordance with QQ-C-320.

9. Sampling
9.1 All faucets of the same type, class, and size offered for delivery at one time shall be considered a lot for purposes of examination and hydrostatic test.

10. Test Methods
10.1 Samples, as specified (see 4.1.13), shall be tested under a hydrostatic pressure of 100 psi (690 kPa).

### TABLE 1 Size and Weight of Type I Faucets

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in.</th>
<th>Minimum Weight, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>3/4</td>
</tr>
<tr>
<td>3/4</td>
<td>7/8</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 1/4</td>
<td>1 1/4</td>
</tr>
</tbody>
</table>

*1 in. = 25.4 mm; 1 lb = 0.45 kg.*
10.1.1 Faucets that do not operate satisfactorily or that show leakage shall not be offered for delivery.

10.2 For Type IX fixtures, samples, as specified (see 4.1.13), shall be tested for metering requirements specified on NAVSEA Drawing 803-5959206 by timing the open to close cycle time at 20-psi (140-kPa) inlet pressure and at 100-psi (690-kPa) inlet pressure.

10.2.1 Cycle time at 20 psi (140 kPa) shall not exceed 20 s, and cycle time at 100 psi (690 kPa) shall not be less than 3 s.

10.2.2 Each sample faucet shall be cycled a minimum of ten times under the pressures noted.

10.2.3 Failure to operate within the specified times or to be tight after each cycle shall be cause for rejection.

11. Inspection

11.1 Sample valves, as specified (see 4.1.13), shall be visually and dimensionally examined to determine conformance with the specified design, inclusion of all required parts, proper assembly, and the existence of proper marking and dimension.

11.2 Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein.

11.2.1 Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein unless disapproved by the purchaser.

11.2.2 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.

11.2.3 The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the purchaser for acceptance comply with all requirements of the contract.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Product Marking

13.1 All handles shall be marked “hot” or “cold” as specified (see 4.1.4). Substitution of “H” or “C” is permissible for “hot” or “cold,” respectively. Type II, Class B and Type IX faucets shall be marked in accordance with NAVSEA Drawing 803-5959206.

13.1.1 Type V faucets shall also have a handle marked with “D” (see Fig. 6).

13.2 Each faucet shall be legibly stamped before, or etched after, plating, with the name or identification mark of the manufacturer.

14. Packaging

14.1 Unless otherwise specified (see 4.1.14), packaging shall conform to the manufacturer’s normal commercial practice, and in such a manner that will ensure acceptance by common carrier and afford protection against physical and mechanical damage during shipment.

14.2 Packing shall be accomplished in a manner that shall ensure acceptance by common carrier at the lowest rate and shall afford protection against physical or mechanical damage during direct shipment from the supply source to the using activity for early installation.

15. Keywords

15.1 compression faucets; faucets; marine; plumbing; self-closing faucets; ship; shipboard

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order (see 4.1.14).

S1. Referenced Documents

S1.1 The following documents are applicable only when one or more of the requirements of S2 or S3 are specified in the contract or order (see 4.1.14): Federal Specifications PPP-B-566, PPP-B-585, PPP-B-591, PPP-B-601, PPP-B-621, PPP-B-636, and PPP-B-676; Military Specification MIL-P-116; Military Standards MIL-STD-105 and MIL-STD-129; and NAVSEA Drawing 805-1623970.

S2. Preparation for Delivery

S2.1 The requirements for packaging, packing, and marking for shipment shall be as specified by the contractor for domestic shipment and storage or overseas shipment.

S2.2 Packaging—The faucets shall be packaged in accordance with Method III of MIL-P-116. Unit and intermediate containers shall conform to PPP-B-566, PPP-B-676, or PPP-B-636. Quantity per unit and intermediate container shall be as specified by the purchaser.

S2.3 Packing shall be Level A or B, as specified (see 4.1.14).

S2.3.1 Level A—The faucets, packaged as specified (see 14.1 or S2.2.1), shall be packed in containers conforming to any one of the following specifications at the option of the supplier: PPP-B-591, Class II; PPP-B-601, overseas type; PPP-B-621, Class 2; PPP-B-585, Class 3; or PPP-B-636, Type SF, weather-resistant class.
S2.3.1.1 The gross weight of wood-type boxes shall not exceed 200 lb (90 kg); fiberboard boxes shall not exceed the weight limitations of the applicable box specification. Closures shall be in accordance with the applicable box specification and appendix thereto.

S2.3.2 Level B—The faucets, packaged as specified (see 14.2 or S2.2.1), shall be packed in containers conforming to any one of the following specifications at the option of the supplier: PPP-B-591, Class I; PPP-B-601, Domestic; PPP-B-621, Class 1; PPP-B-585, Class 1; or PPP-B-636, Type SF, domestic class.

S2.3.2.1 The gross weight of wood-type boxes shall not exceed 200 lb (90 kg); fiberboard boxes shall not exceed the weight limitations of the applicable box specification. Closures shall be in accordance with the applicable box specification and appendix thereto.

S2.4 In addition to any special marking required in the contract or order (see 4.1.14), marking of the packages and shipping containers shall be in accordance with MIL-STD-129.

S2.5 Inspection of Packaging—Sample packages and packs, and the inspection of the preservation packaging, packing, and marking for shipment and storage, shall be in accordance with the requirements of Supplementary Requirement S2 and the documents specified therein.

S3. Special Government Requirements

S3.1 Provisioning:

S3.1.1 Provisioning technical documentation (PTD), spare parts, and repair parts shall be furnished as specified in the contract (see 4.1.14).

S3.1.2 When ordering spare parts or repair parts for the equipment covered by this specification, the contract shall state that such spare parts and repair parts shall meet the same requirements and quality assurance provisions as the parts used in the manufacture of the equipment. Packaging for such parts should also be specified.

S3.1.3 On-board repair parts shall be furnished for shipboard installations in accordance with Table S3.1 for each type valve installed, with the exception of Type IX valves, which shall be in accordance with NAVSEA Drawing 803-5959206.

S3.1.4 Type V faucets and repair parts for Type V faucets are for replacement or repair of existing lavatories only. For lavatories in accordance with NAVSEA Drawing 805-1623970, Type IX, combination water supply and drain fixture shall be supplied.

S3.2 Sampling—Faucets from each lot (see 9.1) shall be selected in accordance with Inspection Level I of MIL-STD-105 for examination (see 11.1) and hydrostatic pressure test (see 10.1). The acceptable quality level (AQL) shall be 1.5 % defective.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete faucet</td>
<td>1 for each 10 faucets installed</td>
</tr>
<tr>
<td>Rubber discs, packing, and seals</td>
<td>100 % for each faucet</td>
</tr>
<tr>
<td>Handles or handwheels</td>
<td>1 for each 10 faucets installed</td>
</tr>
</tbody>
</table>
Standard Practice for Preparing and Locating Emergency Muster Lists

INTRODUCTION

Title 33 and Title 46 of the Code of Federal Regulations (CFR) and the Safety of Life at Sea Convention (SOLAS) contain requirements for muster lists. Emergency muster lists are required to be on board tank vessels, passenger vessels, cargo vessels, oceanographic research vessels, nautical school ships, mobile offshore drilling units (MODUs), and outer continental shelf (OCS) facilities other than MODUs. This practice is a consolidated source for muster list requirements, combining requirements from all of the subparts of the Code of Federal Regulations listed above and SOLAS 1974 as amended through 1996.

1. Scope

1.1 This practice sets forth the elements to be included in an emergency muster list, including emergency signals, and its location on a vessel or facility. This practice also includes emergency instructions for passengers.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 Code of Federal Regulations:
Title 33 Navigation and Navigable Waters
Title 46 Shipping
2.2 Safety of Life at Sea Convention.
SOLAS 74 Internation Convention for the Safety of Life at Sea, 1974 (as amended)

2.3 Other Document:
IMO Resolution A.760(18) Symbols Related to Life-Saving Appliances and Arrangements

3. Significance and Use

3.1 Muster lists are intended to provide both an effective plan for assigning personnel stations and duties in the event of any foreseeable emergency, as well as a quick visual reference that a crewmember can look at to find out where to go, what to bring, and what duties to perform in the event of an emergency and must be posted at all times.

3.2 The station bill has been changed to muster list. The term station bill may be used optionally.

3.3 Since no two classes of vessels or facilities are identical, muster lists must be tailored for individual vessels or facilities.

3.4 Muster lists are intended to be posted in conspicuous locations throughout the vessel for the use of the crew.

3.5 Posted muster lists shall be at least 600 by 750 mm (24 by 30 in.).

3.6 Muster lists shall outline the special duties and duty stations for each member of the crew, including the chain of command, for the various emergencies.

3.7 As far as possible, duties shall be comparable with the regular work of the individual.

3.8 The muster list shall set forth the various signals to be used for the calling of the crew to their stations and for giving instructions to them while at their stations as outlined in Section 4.

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This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.


^1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.


^4 Available from the International Maritime Organization, 4 Albert Embankment, London SE1 7SR, UK.
3.9 The muster list shall illustrate the purpose of controls.
3.10 The muster list shall illustrate the procedure for operating the launching device.
3.11 The muster list shall give relevant instructions or warnings.
3.12 The muster list should be able to be seen easily under emergency lighting conditions.
3.13 The muster list must also display the symbols in accordance with IMO Resolution A.760(18).
3.14 The final muster list should be as simple as possible; and an accurate and up-to-date muster list should be maintained.

4. Procedure

4.1 Fig. 1 is provided as a sample muster list.
4.2 Each muster list shall be at least poster size (600 by 750 mm (24 by 30 in.
).
4.3 Each muster list shall specify the following:
4.3.1 Instructions for operating the general alarm system,
4.3.2 Identification of the emergency signals,
4.3.3 The action to be taken by crew and passengers when each signal is sounded,
4.3.4 How the order to abandon the vessel will be given,
4.3.5 The survival craft to which each person on board is assigned,
4.3.6 The officers who are assigned to ensure that lifesaving and fire-fighting appliances are maintained in good condition and are ready for immediate use,
4.3.7 Substitutes for key persons in the event that those persons are disabled, taking into account that different emergencies require different actions,
4.3.8 The duties assigned to the different members of the crew, including:
4.3.8.1 Persons in command and the chain of command,
4.3.8.2 Closing of watertight doors, fire doors, valves, scuppers, sidescuttles, skylights, portholes, and other similar openings in the vessel’s hull,
4.3.8.3 Stopping of fans and ventilating systems,
4.3.8.4 Equipping survival craft and other lifesaving appliances,
4.3.8.5 Preparation and launching of survival craft,
4.3.8.6 General preparations of other lifesaving appliances,
4.3.8.7 Muster of passengers and other persons in addition to the crew,
4.3.8.8 Use of communication equipment,
4.3.8.9 Responsibility for two-way radiotelephone apparatus and other portable emergency radiocommunication equipment not stowed in survival craft or rescue boats,
4.3.8.10 Manning of rescue boats for rescuing persons overboard and other emergencies requiring the use of the rescue boat,
4.3.8.11 Manning of emergency squad assigned to deal with fires and other emergencies,
4.3.8.12 Administration of first aid,
4.3.8.13 The passenger vessel muster list should include the procedures for locating and rescuing persons who may be trapped in the staterooms,
4.3.8.14 Special duties assigned with respect to the use of fire-fighting equipment and installations, and
4.3.8.15 Such other duties as are necessary for the proper handling of the vessel in an emergency.
4.3.9 The duties assigned to members of the crew, generally from the steward’s department, in relation to passengers in case of emergency, including:
4.3.9.1 Warning passengers and other persons on board,
4.3.9.2 Seeing that passengers are suitably dressed and have donned their lifejackets or immersion suits correctly,
4.3.9.3 Assembling passengers at muster stations,
4.3.9.4 Keeping order in the passageways and on the stairways and generally controlling the movements of the passengers, and
4.3.9.5 Making sure that a supply of blankets is taken to survival craft.
4.4 Where the size of the crew permits, the muster list on a passenger vessel shall include an emergency squad organized by the master to form the nucleus of a damage control party. This squad consists of persons specially trained in the use of the emergency and rescue equipment and generally familiar with the vessel and fundamentals of damage control.
4.5 On MODUs and OCS facilities, the requirements in 4.3 applying to the crew also include the industrial personnel assigned to the unit. The requirements in 4.3 that apply to passengers also apply to visitors and other persons on board not regularly employed on the unit. In addition to the requirements in 4.3, the muster list shall cover the following:
4.5.1 The duties of the crew in case of collisions or other serious casualties, and
4.5.2 The duties of the crew in case of severe storms.
4.6 Emergency instructions and illustrations for posting in passenger cabins and at muster stations shall be in English and may also be in any other appropriate language. The instructions and illustrations shall inform passengers of the following:
4.6.1 The fire and emergency signal,
4.6.2 The abandon ship signal,
4.6.3 Their muster station,
4.6.4 The essential actions they shall take in an emergency,
4.6.5 The method of donning lifejackets, incorporating fully illustrated instructions,
4.6.6 The location of immersion suits and lifejackets, if they are provided for passengers, including child-size immersion suits and lifejackets,
4.6.7 The method of donning immersion suits, if immersion suits are provided for passengers, including fully illustrated instructions, and
4.6.8 The location of thermal protective aid for each person not provided with an immersion suit on passenger vessels.
4.7 The muster list for nautical school ships shall include the muster of all persons aboard in the duties assigned.
4.8 Vessels other than MODUs and OCS facilities shall use the following signals:
4.8.1 The fire alarm signal shall be a continuous blast of the whistle for not less than 10 s supplemented by the continuous ringing of the general alarm bells for not less than 10 s.
4.8.2 For dismissal from fire alarm stations, the general alarm shall be sounded three times supplemented by three short blasts of the whistle.
**MUSTER LIST**

**GENERAL INSTRUCTIONS**

1. Each crew member shall familiarize himself/herself with the location of his/her respective station and assigned duties immediately reporting aboard.

2. All persons reporting to emergency stations shall be fully dressed including a hat and shoes, and shall carry a flashlight, if possible.

3. Immediately upon sounding of an alarm contact shall be made by the Department Heads with the Master. Channel 1 is the designated Emergency Channel on the Handi-Talkie. All initial contact persons with duties listed below are to furnish specific information to the Department Heads until requested by the Captain.

4. A person discovering a fire shall immediately notify the Captain who shall immediately report the fire by any available means.

5. Upon hearing a "Man Overboard", immediately throw a life preserver into the water and pass the word to the bridge "Man Overboard Port/Starboard Side" if in sight the lifeguard should keep lifeguard at a safe distance.

6. In an emergency and for all drills, extra persons will muster at the hospital/treatment room.

**FIRE AND EMERGENCY STATIONS**

**FIRE AND EMERGENCY SIGNAL**

Continuous sounding of the ship's whistle for a period of not less than ten (10) seconds supplemented by the same signal on the General Alarm Bell.

**DISMISSEL SIGNAL**

Three (3) short blasts of the ship's whistle supplemented by the same signal on the General Alarm Bell.

**MAN OVERBOARD SIGNAL**

Sounding of the letter "M" on the ship's whistle several times and then supplemented by the same signal on the General Alarm Bell.

**NOTE:** Extra persons will muster at the hospital/treatment room.

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**ABANDON SHIP STATIONS**

Severe (3) short blasts on the whistle followed by one (1) long blast, supplemented by the same signal on the General Alarm Bell.

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**PREPARE BOAT FOR Launching — Lifeboat No. 3**

- **First Mate**
- **Second Assistant Engineer**
- **Engine Cadet**
- **General Steward (Chief)**

**WAVING**

- **Chief Engineer**
- **Second Assistant Engineer**
- **Engine Cadet**
- **General Steward (Chief)**

**PREPARE BOAT FOR Launching — Lifeboat No. 1**

- **First Mate**
- **Second Assistant Engineer**
- **Engine Cadet**
- **General Steward (Chief)**

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**STARBORD**

- **Master**
- **Second Mate**
- **Third Mate**
- **Chief Engineer**
- **Second Assistant Engineer**
- **Engine Cadet**
- **General Steward (Chief)**

**WARNING**

- **Chief Engineer**
- **Second Assistant Engineer**
- **Engine Cadet**
- **General Steward (Chief)**

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**FIG. 1 Sample Format for Must List**

3
4.8.3 The signal for boat stations or abandon ship drill shall be a succession of more than six short blasts followed by one long blast of the whistle supplemented by a comparable signal on the general alarm bells.

4.8.4 Where whistle signals are used to handle the lifeboats and davit-launched life rafts, they shall be as follows:
   4.8.4.1 To lower the lifeboats and davit-launched life rafts, one short blast, and
   4.8.4.2 To stop lowering the lifeboats and davit-launched life rafts, two short blasts.

4.8.5 For dismissal from boat stations, there shall be three short blasts of the whistle.

4.8.6 In the case of river vessels, the ship’s bell may be used instead of the whistle signals stipulated in this section.

4.8.7 The master of any vessel may establish such other emergency signals, in addition to 4.8.1 through 4.8.6, as will provide that all officers, crew, and passengers will have positive and certain notice of the existing emergency. Each additional emergency signal established shall not conflict with navigational signals or other general alarm signals.

4.9 Muster lists for MODUs and OCS facilities other than MODUs shall include instructions on the following additional items:
   4.9.1 Warning personnel of the emergency,
   4.9.2 Instructing all personnel on use and wearing of life preservers and exposure suits (if carried), and
   4.9.3 Directing personnel to appointed stations.

4.9.4 The muster list shall set forth signals that accomplish the following:
   4.9.4.1 Call personnel to their stations, and
   4.9.4.2 Direct personnel at their stations.

4.10 Emergency stations signals for MODUs and OCS facilities other than MODUs are established as follows:
   4.10.1 The signal to man emergency stations is a rapid succession of short soundings of both the general alarm bell and the whistle, if a whistle is installed, for a period of not less than 10 s.
   4.10.2 The signal to secure from emergency stations is three short soundings of both the general alarm bell and the whistle, if a whistle is installed.
   4.10.3 The signal to man abandoned unit stations is a continuous sounding of both the general alarm and the whistle, if a alarm and the whistle, if a whistle is installed.
   4.10.4 If whistle signals are used to direct handling of lifeboats and davit-launched life rafts, they shall be sounded as follows:
      4.10.4.1 One short blast to lower lifeboats and davit-launched life rafts, and
      4.10.4.2 Two short blasts to stop lowering the lifeboats and davit-launched life rafts.
   4.10.5 The signal to secure from abandoned unit stations is three short soundings of both the general alarm bell and the whistle, if a whistle is installed.

5. Keywords
   5.1 chain of command; Code of Federal Regulations Title 33; Code of Federal Regulations Title 46; duty station; emergency instructions; emergency signals; emergency muster lists; marine; muster list posting; muster lists; Safety of Life at Sea; ship; SOLAS; special duties
Standard Specification for
Spill Valves for Use in Marine Tank Liquid Overpressure
Protections Applications

1. Scope
1.1 This specification provides the minimum requirements for design, construction, performance, and testing of devices to prevent marine tank liquid overpressurization (hereafter called spill valves).
1.2 The spill valves provided in accordance with this specification will satisfy Regulation II-2/59.1.6 of the 1981 and 1983 Amendments to the International Convention for the Safety of Life at Sea, 1974 (SOLAS), which states: “Provision shall be made to guard against liquid rising in the venting system to a height which would exceed the design head of the cargo tank. This shall be accomplished by high level alarms or overflow control systems or other equivalent means, together with gaging devices and cargo tank filling procedures.”
1.3 The spill valves are not intended for the venting of vapors or the relief of vapor overpressurization or underpressurization of marine tanks.
1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.
1.5 The following precautionary caveat pertains only to the test methods portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents
2.1 ASTM Standards:
   B 117 Practice for Operating Salt Spray (Fog) Apparatus
   F 722 Specification for Welded Joints for Shipboard Piping Systems
2.2 ANSI Standards:
   B 2.1 Pipe Threads
   B 16.1 Cast Iron Pipe Flanges and Flanged Fittings
   B 16.3 Malleable Iron Threaded Fittings
   B 16.4 Cast Iron Threaded Fittings
   B 16.5 Steel Pipe Flanges and Flanged Fittings
   B 16.11 Forged Steel Fittings, Socket-Welding and Threaded
   B 16.15 Cast Bronze Threaded Fittings
   B 16.24 Bronze Pipe Flanges and Flanged Fittings
   B 31.1 Power Piping
2.3 Other Documents:
   ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels; Section IX, Welding and Brazing Qualifications
   Safety for Life at Sea Convention, Regulation II-2/59.1.6, Amendments 1981 and 1983
   46 CFR 153 Ships Carrying Bulk Liquid, Liquified Gas, or Compressed Gas Hazardous Materials

3. Terminology
3.1 Definition:
3.1.1 spill valve—an independent device that automatically prevents liquid overpressurization of a tank by relieving liquid at a predetermined pressure set higher than the pressure reached in the tank when the tank vapor relieving device operates at its maximum design venting rate (based on a volumetric vapor volume 1.25 times the maximum design loading rate).

4. Ordering Information
4.1 Orders for spill valves in accordance with this specification shall include the following information, as applicable:
4.1.1 Nominal pipe size and end connections,
4.1.2 Product(s) in tank being protected by the spill valve,
4.1.3 Inspection and tests other than specified by this specification,
4.1.4 Required relieving pressure at maximum tank loading flow rate,

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.

2 Annual Book of ASTM Standards, Vol 03.02.


4 Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

5 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

qualified in accordance with Section IX of the ASME Code.

4.1.7 Inlet pressure drop resulting from the maximum tank design loading flow rate.

4.1.9 Purchaser’s inspection requirements (see 9.1).

4.1.10 Installation inclinations in excess of 2 1/2 ° (see 6.6).

4.1.11 Purchaser’s specifications for preventing the valve from leaking due to cargo sloshing, and

4.1.12 Additional requirements or testing as contracted by the manufacturer and the purchaser.

5. Materials

5.1 Materials of construction shall be suitable for the service intended and resistant to the attack by the liquid carried in the tank being protected (see 4.1.2). Table I of 46 CFR 153 specifies materials that may not be used in components that contact liquid or vapor of each hazardous liquid cargo.

5.2 Housings of spill valves, and all other parts or bolting, or both, used for pressure retention, shall be constructed of materials having a solidus melting point of greater than 1700°F (927°C) and be listed in ANSI B 31.1 or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, except as noted in 5.5.

5.3 Corrosion-resistant materials shall be used for the following:

5.3.1 Housings, disks, spindles, and seats of valves.

5.3.2 Springs that actuate disks of valves. Springs plated with corrosion-resistant material are not acceptable.

5.4 Nonmetallic materials shall not be permitted except for gaskets, seals, bushings in way of moving parts, and valve diaphragms.

5.5 Bolting materials shall be at least equal to those listed in Table 1 of ANSI B 16.5. Bolts, screws, and fasteners in contact with interior liquid shall be compatible with the liquid (see 4.1.2).

6. Other Requirements

6.1 Pressure-retaining housings shall be designed to withstand a hydrostatic pressure of at least 125 lb/in.² (8.78 kg/cm²) without rupturing or showing permanent distortion.

6.2 Housing shall have suitable pipe connections for the removal, maintenance, and testing of the spill valve.

6.2.1 Threaded or flanged pipe end connections shall comply with the applicable B 16 ANSI standards listed in 2.2 or as agreed upon by the manufacturer and the purchaser (see 4.1.12). Welded joints shall comply with Specification F 722.

6.3 The design of spill valves shall allow for ease of inspection and removal of internal elements for replacement, cleaning, or repair without removal of the spill valve.

6.4 All flat joints of the housing shall be machined true and shall provide for a joint having adequate metal-to-metal contact.

6.5 Where welded construction is used, welded joint design details, welding, and nondestructive testing shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F 722. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.

6.6 The spill valve shall be fully operable at static inclinations up to 2 1/2 ° unless otherwise specified by the ordering information in Section 4.

6.7 Spill valves shall allow for efficient drainage of moisture without impairing their proper operation.

6.7.1 Where the design does not permit complete drainage of condensate through its connection to the tank, the housing shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than nominal pipe size 1/2 in. (12 mm).

6.8 Housing, elements, and seal gasket materials shall be capable of withstanding the highest pressure and temperature to which the spill valve may be exposed under normal conditions.

6.9 Spill valves shall be vapor tight at pressures below the rated liquid relieving pressure.

6.10 Fastenings essential to the operation of the spill valve shall be protected against loosening.

6.11 Spill valves shall be designed and constructed to minimize the effect of fouling under normal conditions.

6.12 The spill valve shall not be provided with a means of positive closure. In installations where cargo sloshing is expected, the spill valve installation must be designed to preclude premature opening of the valve due to cargo sloshing. Also, the installation shall be designed so that it complies with applicable loadline and subdivision requirements.

6.13 Spill valves shall be capable of operating in freezing conditions.

6.14 Each of the free areas through the valve seat and through the valve discharge at maximum lift shall not be less than the cross-sectional area of the valve inlet connection.

6.15 Means shall be provided to check that any valve opens freely and does not remain lodged in the open position.

6.16 Valve Disks:

6.16.1 Valve disks shall be guided by a ribbed cage or other suitable means to prevent binding and ensure proper seating. Where valve stems are guided by bushings suitably designed to prevent binding and to ensure proper seating, the valves need not be fitted with ribbed cages.

6.16.2 Valve disks shall close tight against the valve seat by metal to metal contact; however, resilient seating seals may be provided if the design is such that the disk closes tight against the seat in case the seals are destroyed or in case they carry away.

6.16.3 Valve disks may be solid or hollow. The pressure at which the valve disks open fully at maximum flow rating shall not exceed 120 % of the set (opening) pressure.

6.17 Valves may be actuated by nonmetallic diaphragms.

6.17.1 Nonmetallic diaphragms are not allowed where failure results in unrestricted flow of flammable or toxic tank vapors to the atmosphere or in an increase in the pressure at which the valve normally releases.

6.18 Relief pressure adjusting mechanisms shall be permanently secured by lockwire, locknuts, or other suitable means.

6.18.1 Hollow portions of the valve used to vary the relieving pressure by adding or removing weight shall be watertight.
6.18.2 Spill valves shall not permit entrance of water when exposed to boarding seas.

7. Workmanship, Finish, and Appearance

7.1 Spill valves shall be of first class workmanship and free from imperfections that may affect their intended purpose.

7.2 Each finished spill valve shall be visually and dimensionally checked to ensure that the spill valve corresponds to this specification, is certified in accordance with Section 10, and is marked in accordance with Section 11.

8. Test Methods

8.1 Prototype Tests:

8.1.1 A prototype of the largest and smallest spill valve of each design, based on valve inlet connection size, shall be tested as specified in 8.1.5, 8.1.6, and8.1.8 through 8.1.10. Additionally, all models shall be tested as specified in 8.1.7.

8.1.2 The spill valve shall have the dimensions of and most unfavorable clearances expected in production units.

8.1.3 Tests shall be conducted by a laboratory capable of performing the tests.

8.1.4 A test report shall be prepared by the laboratory that shall include:

8.1.4.1 Detailed drawings of the spill valve,
8.1.4.2 Types of tests conducted and results obtained,
8.1.4.3 Specific advice on approved attachments,
8.1.4.4 Types of liquid for which the spill valve is approved,
8.1.4.5 Drawings of the test rig,
8.1.4.6 The pressures at which the spill valve opens and closes and the efflux flow rate at various inlet pressures,
8.1.4.7 Records of all markings found on the prototype spill valve, and
8.1.4.8 A traceable report number.

8.1.5 Corrosion Test—A corrosion test shall be conducted in accordance with Practice B 117. The valve shall be subjected to the test for a period of 240 h and allowed to dry for 48 h. There shall be no corrosion deposits that cannot be washed off.

8.1.6 Hydrostatic Test—A hydrostatic pressure test shall be conducted to show compliance with 6.1. The test shall be made with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 1 min. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.1.7 Performance Tests—Performance characteristics, including flow rates under various positive pressures, operating sensitivity, flow resistance, and velocity, shall be demonstrated by appropriate tests with a representative fluid.

8.1.8 Freeze Test—Simulate water sloshing on deck by spraying a prototype spill valve completely with water from all sides and below using a fully pressurized fire hose. Allow 3 min to drain off. Immediately immerse it in a freeze chamber prechilled to 20°F (-7°C). Hold it in a chamber for 2 h at this temperature. Immediately test the valve as in 8.1.7 to determine opening pressure while frozen. The unit passes the test if it opens within 10 % of its previously measured set (opening) pressure.

8.1.9 Vapor Tightness Test—Compliance with 6.9 shall be demonstrated by testing the spill valve with compressed air at 90 % of the spill valve set (opening) pressure. The test apparatus shall have a total volume of air (in cubic feet) equal to 5 x D, where D is the seat diameter of the spill valve, in inches (test volume may vary by ±10 %). The valve design shall be deemed satisfactory if the air leakage rate is such that the pressure drop is not more than 2 % in 2 h.

8.1.10 Seaworthiness Test—In a simulated installation, immerse the spill valve such that the seal is under 2 ft of water, minimum. Spray it for 10 min with a 2½-in. fire hose with a fully open 7½-in. diameter nozzle at a pitot pressure of 80 psig measured at the open nozzle. Spray all parts of the valve, both immersed and non-immersed, from all angles. The hose nozzle shall not be located further than 10 ft from the spill valve during the course of this test. The valve design is sufficient if leakage through the housing or past the disk, or both, is no more than 1 oz.

8.1.11 After completion of all tests the device shall be disassembled and examined and no part of the device shall be damaged or show permanent deformation.

8.2 Production Tests:

8.2.1 Each finished spill valve is to be tested by a hydrostatic test conducted at 1½ times the rated relieving pressure of the spill valve, with the device secured closed. The test shall be made with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 1 min. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.2.2 Before being shipped, each unit shall be tested as necessary to verify that it will function at its set (opening) pressure and that the disk moves freely and fully.

9. Inspection

9.1 The manufacturer shall afford the purchaser’s inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer’s operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

10. Certification

10.1 Manufacturer’s certification that a spill valve has been constructed in accordance with this specification shall be provided in an instruction manual. The manual shall include the following:

10.1.1 Installation instructions, including size of the inlet and outlet, approved location for installation, and maximum or minimum length of pipe, if any, between the spill valve and the atmosphere,
10.1.2 Operating instructions,
10.1.3 Maintenance requirements,
10.1.3.1 Instructions on how to determine when spill valve cleaning is required and the method of cleaning,
10.1.4 Copy of prototype test report (see 8.1), and
10.1.5 Product(s) that the valve is designed for or restricted to, or both.
11. Product Marking

11.1 Each spill valve shall be permanently marked indicating the following:

11.1.1 Manufacturer’s name or trademark,
11.1.2 Style, type, model, or other manufacturer’s designation for the spill valve,
11.1.3 Direction of flow through the spill valve,
11.1.4 Maximum rated flow,
11.1.5 ASTM designation of this specification,
11.1.6 Relief pressure setting at full flow rating,
11.1.7 Set (opening) pressure, and
11.1.8 Indication of proper orientation of valve, if critical.

12. Quality Assurance

12.1 Spill valves shall be designed, manufactured, and tested in a manner that ensures they meet the characteristics of the prototype tested in accordance with this specification.

12.2 The spill valve manufacturer shall maintain the quality of the spill valves that are designed, tested, and marked in accordance with this specification. At no time shall a spill valve be sold with this specification designation that does not meet the requirements herein.

13. Keywords

13.1 marine technology; overflow control systems; overpressurization; overpressure protection; ships; spill valves

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Standard Specification for Tank Vent Flame Arresters

This standard is issued under the fixed designation F 1273; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides the minimum requirements for design, construction, performance, and testing of tank vent flame arresters.

1.2 This specification is intended for flame arresters protecting systems containing vapors of flammable or combustible liquids where vapor temperatures do not exceed 60°C. The test media defined in 9.1.1 can be used except where arresters protect systems handling vapors with a maximum experimental safe gap (MESG) below 0.9 mm. Flame arresters protecting such systems must be tested with appropriate media (the same vapor or a media having a MESG no greater than the vapor). Various gases and their respective MESG are listed in Table 1.

NOTE 1—Flame arresters meeting this specification also comply with the minimum requirements of the International Maritime Organization, Maritime Safety Committee Circular No. 373 (MSC/Circ. 373/Rev. 1).

1.3 The values stated in either inch-pound or SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following precautionary caveat pertains only to the test methods portions, Sections 8 and 9, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.5 This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use

2. Referenced Documents

2.1 ASTM Standards:

F 722 Specification for Welded Joints for Shipboard Piping Systems

F 1155 Practice for Selection and Application of Piping System Materials

2.2 ANSI Standard:

TABLE 1 Gases and Their MESGs

<table>
<thead>
<tr>
<th>Inflammable Gas or Vapor</th>
<th>Maximum Experimental Safe Gap</th>
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<tr>
<td></td>
<td>mm</td>
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<td></td>
<td>in.</td>
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<tr>
<td>Methane</td>
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<td>Blast furnace gas</td>
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<tr>
<td>Propane</td>
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<tr>
<td>Butane</td>
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<td>Pentane</td>
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<td>Hexane</td>
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<td>Iso-octane</td>
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<td>Propyl-acetate</td>
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<td>Butyl-acetate</td>
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<td>Methyl alcohol</td>
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<td>Ethyl alcohol</td>
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<td>Iso-butyl-alcohol (normal)</td>
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<tr>
<td>Butyl-alcohol (normal)</td>
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<td>Amyl-alcohol</td>
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<td>Ethyl-ether</td>
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<td>Coal gas (H2 57 %)</td>
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<td>Acetylene</td>
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<td>Hydrogen</td>
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<td>Blue water gas (H2 53 % CO 47 %)</td>
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F 722 Specification for Welded Joints for Shipboard Piping Systems

F 1155 Practice for Selection and Application of Piping System Materials

B16.5 Pipe Flanges and Flanged Fittings3
2.3 Other Documents:
ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Pressure Vessels4
ASME Boiler and Pressure Vessel Code: Section IX, Welding and Brazing Qualifications4
International Maritime Organization, Maritime Safety Committee: MSC/Circ. 373/Rev. 1 Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers5
International Electrotechnical Commission: Publication 79-1 Electrical Apparatus for Explosive Gas Atmospheres6

3. Terminology
3.1 Definitions:
3.1.1 flame arrester—a device to prevent the passage of flame in accordance with a specified performance standard. Its flame arresting element is based on the principle of quenching.
3.1.2 flame passage—the transmission of a flame through a flame arrester.
3.1.3 flame speed—the speed at which a flame propagates along a pipe or other system.
3.1.4 gasoline vapors—a nonleaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds with a boiling range of approximately 65 to 75°C.

4. Classification
4.1 The two types of flame arresters covered in this specification are classified as follows:
4.1.1 Type I—Flame arresters acceptable for end-of-line applications.
4.1.2 Type II—Flame arresters acceptable for in-line applications.

5. Ordering Information
5.1 Orders for flame arresters under this specification shall include the following information, as applicable:
5.1.1 Type (I or II),
5.1.2 Nominal pipe size,
5.1.3 Each gas or vapor in the tank being protected by the flame arrester and the corresponding MESG,
5.1.4 Inspection and tests other than those specified by this specification,
5.1.5 Anticipated ambient air temperature range,
5.1.6 Purchaser’s inspection requirements (see 10.1),
5.1.7 Description of installation (distance and configuration of pipe between the arrester and the atmosphere or potential ignition source) (see 8.2.4.2),
5.1.8 Materials of construction (see Section 6), and
5.1.9 Maximum flow rate and the design pressure drop for that maximum flow rate.

6. Materials
6.1 The flame arrester housing, and other parts or bolting used for pressure retention, shall be constructed of materials listed in Practice F1155, or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.
6.1.1 Arrester, elements, gaskets, and seals shall be of materials resistant to attack by seawater and the liquids and vapors contained in the tank being protected (see 5.1.3).
6.2 Nonmetallic materials, other than gaskets and seals, shall not be used in the construction of pressure-retaining components of the flame arrester.
6.2.1 Nonmetallic gaskets and seals shall be noncombustible and suitable for the service intended.
6.3 Bolting materials, other than those in 6.1, shall be at least equal to those listed in Table 1 of ANSI B16.5.
6.4 The possibility of galvanic corrosion shall be considered in the selection of materials.
6.5 All other parts shall be constructed of materials suitable for the service intended.

7. Other Requirements
7.1 Flame arrester housings shall be gastight to prevent the escape of vapors.
7.2 Flame arrester elements shall fit in the housing in a manner that will ensure tightness of metal-to-metal contacts in such a way that flame cannot pass between the element and the housing.
7.2.1 The net free area through flame arrester elements shall be at least 1.5 times the cross-sectional area of the arrester inlet.
7.3 Housings and elements shall be of substantial construction and designed for the mechanical and other loads intended during service. In addition, they shall be capable of withstanding the maximum and minimum pressures and temperatures to which the device may be exposed under both normal and the specified fire test conditions in Section 9.
7.4 Threaded or flanged pipe connections shall comply with the applicable B-16 standards in Practice F1155. Welded joints shall comply with Specification F722.
7.5 All flat joints of the housing shall be machined true and shall provide for a joint having adequate metal-to-metal contact.
7.6 Where welded construction is used for pressure-retaining components, welded joint design details, welding, and nondestructive testing shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F722. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.
7.7 The design of flame arresters shall allow for ease of inspection and removal of internal elements for replacement, cleaning, or repair without removal of the entire device from the system.
7.8 Flame arresters shall allow for efficient drainage of condensate without impairing their efficiency to prevent the passage of flame.
7.8.1 Where the design does not permit complete drainage of condensate through its connection to the tank, the housing shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than \( \frac{1}{2} \)-in. nominal pipe size (NPS \( \frac{1}{2} \)).

7.9 All fastenings shall be protected against loosening.

7.10 Flame arresters shall be designed and constructed to minimize the effect of fouling under normal operating conditions.

7.11 Flame arresters shall be capable of operating over the full range of ambient air temperatures anticipated.

7.12 End-of-line flame arresters shall be so constructed as to direct the efflux vertically upward.

7.13 Flame arresters shall be of first class workmanship and free from imperfections that may affect their intended purpose.

7.14 Tank vent flame arresters shall show no flame passage when subjected to the tests in 8.2.4.

8. Prototype Tests

8.1 Tests shall be conducted by an independent laboratory capable of performing the tests. The manufacturer, in choosing a laboratory, accepts that it is a qualified independent laboratory by determining that it has (or has access to) the apparatus, facilities, personnel, and calibrated instruments that are necessary to test flame arresters in accordance with this specification.

8.1.1 A test report shall be prepared by the laboratory that shall include the following:

8.1.1.1 Detailed drawings of the flame arrester and its components (including a parts list identifying the materials of construction).

8.1.1.2 Types of tests conducted and results obtained,

8.1.1.3 Specific advice on approved attachments (see 8.2.4.1),

8.1.1.4 Types of gases or vapors for which the flame arrester is approved (see 5.1.3),

8.1.1.5 Drawings of the test rig,

8.1.1.6 Records of all markings found on the tested flame arrester, and

8.1.1.7 A report number.

8.2 One of each model Type I and Type II flame arrester shall be tested. Where approval of more than one size of a flame arrester model is desired, the largest and smallest sizes shall be tested. A change of design, material, or construction that may affect the corrosion resistance, endurance burn, or flashback capabilities of the flame arrester shall be considered a change of model.

8.2.1 The flame arrester shall have the same dimensions, configuration, and the most unfavorable clearances expected in production units.

8.2.2 A corrosion test shall be conducted. In this test, a complete arrester, including a section of pipe similar to that to which it will be fitted, shall be exposed to a 20% sodium chloride solution spray at a temperature of 25°C for a period of 240 h and allowed to dry for 48 h. Following this exposure, all movable parts shall operate properly and there shall be no corrosion deposits that cannot be washed off.

8.2.3 Performance characteristics as declared by the manufacturer, such as flow rates under both positive and negative pressure, operating sensitivity, flow resistance, and velocity, shall be demonstrated by appropriate tests.

8.2.4 Tank vent flame arresters shall be tested for endurance burn and flashback in accordance with the test procedures in Section 9. The following constraints apply:

8.2.4.1 Where a Type I flame arrester is provided with cowls, weather hoods, deflectors, and so forth, it shall be tested in each configuration in which it is provided.

8.2.4.2 Type II arresters shall be specifically tested with the inclusion of all pipes, tees, bends, cowls, weather hoods, and so forth, which may be fitted between the arrester and the atmosphere.

8.2.5 Devices that are provided with a heating arrangement shall pass the required tests at the heated temperature.

8.2.6 After all tests are completed, the device shall be disassembled and examined, and no part of the device shall be damaged or show permanent deformation.

9. Test Procedures for Flame Arresters

9.1 Media/Air Mixtures:

9.1.1 For vapors from flammable or combustible liquids with a MESG greater than or equal to 0.9 mm, technical grade hexane or gasoline vapors shall be used for all tests in this section, except technical grade propane may be used for the flashback test in 9.2. For vapors with a MESG less than 0.9 mm, the specific vapor (or alternatively, a media with a MESG less than or equal to the MESG of the vapor) shall be used as the test medium in all Section 9 tests.

9.1.2 Hexane, propane, gasoline, and chemical vapors shall be mixed with air to form the most easily ignitable mixture. 7

9.2 Flashback Test:

9.2.1 A flashback test shall be carried out as follows:

9.2.1.1 The test rig shall consist of an apparatus producing an explosive mixture, a small tank with a diaphragm, a prototype of the flame arrester, a plastic bag, and a firing source in three positions (see Fig. 1). 9

9.2.1.2 The tank, flame arrester assembly, and plastic bag enveloping the prototype flame arrester shall be filled so that this volume contains the most easily ignitable vapor/air mixture. 7 The concentration of the mixture should be verified by appropriate testing of the gas composition in the plastic bag. Three ignition sources shall be installed along the axis of the bag, one close to the flame arrester, another as far away as possible therefrom, and the third at the midpoint between these two. These three sources shall be fired in succession, one during each of the three tests. Flame passage shall not occur during this test.

9.2.1.3 If flame passage occurs, the tank diaphragm will burst and this will be audible and visible to the operator by the emission of a flame. Flame, heat, and pressure sensors may be used as an alternative to a bursting diaphragm.

7 See IEC Publication 79-1.

8 The dimensions of the plastic bag are dependent on those of the flame arrester. The plastic bag may have a circumference of 2 m, a length of 2.5 m, and a wall thickness of 0.05 m.

9 To prevent remnants of the plastic bag from falling back onto the flame arrester being tested after ignition of the fuel/air mixture, it may be useful to mount a coarse wire frame across the flame arrester within the plastic bag. The frame should be constructed so as not to interfere with the test result.
9.3 Endurance Burn Test:

9.3.1 An endurance burning test shall be carried out as follows:

9.3.1.1 The test rig referred to in 9.2.1.1 may be used, without the plastic bag. The flame arrester shall be so installed that the mixture emission is vertical. The mixture shall be ignited in this position.

9.3.1.2 Endurance burning shall be achieved by using the most easily ignitable test vapor/air mixture with the aid of a pilot flame or a spark igniter at the outlet. By varying the proportions of the flammable mixture and the flow rate, the arrester shall be heated until the highest obtainable temperature on the cargo tank side of the arrester is reached. The highest attainable temperature may be considered to have been reached when the rate of temperature increase does not exceed 0.5°C per minute over a 10-min period. This temperature shall be maintained for a period of 10 min, after which the flow shall be stopped and the conditions observed. If difficulty arises in establishing the highest attainable temperature, the following criteria shall apply. When the temperature appears to be approaching the maximum temperature, using the most severe conditions of flammable mixtures and flow rate, but increases at a rate in excess of 0.5°C per minute over a 10-min period, endurance burning shall be continued for a period of 2 h, after which the flow shall be stopped and the conditions observed. Flame passage shall not occur during this test.

10. Inspection

10.1 The manufacturer shall afford the purchaser’s inspector all reasonable facilities necessary to ensure that the material is being furnished in accordance with this specification. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

10.2 Each finished flame arrester shall be visually and dimensionally checked to ensure that the device corresponds to this specification, is certified in accordance with Section 11, and is marked in accordance with Section 12. Special attention shall be given to checking the proper fit-up of joints (see 7.5 and 7.6).

11. Certification

11.1 Manufacturer’s certification that a flame arrester has been constructed in accordance with this specification shall be provided in an instruction manual. The manual shall include the following, as applicable:

11.1.1 Installation instructions and a description of all configurations tested (see 8.2.4.1 and 8.2.4.2). Installation instructions to include manufacturer’s recommended limitations based on all configurations tested.

11.1.2 Operating instructions.

11.1.3 Maintenance requirements.

11.1.3.1 Instructions on how to determine when flame arrester cleaning is required and the method of cleaning.

11.1.4 Copy of the test report (see 8.1.1).

11.1.5 Flow test data, including flow rates under both positive and negative pressures, operating sensitivity, flow resistance, and velocity.

11.1.6 The ambient air temperature range over which the device will effectively prevent the passage of flame.

NOTE 2—Other factors such as condensation and freezing of vapors should be evaluated at the time of equipment specification.

12. Product Marking

12.1 Each flame arrester shall be permanently marked indicating:

12.1.1 Manufacturer’s name or trademark,

12.1.2 Style, type, model, or other manufacturer’s designation for the flame arrester,

12.1.3 Size of the inlet and outlet,

12.1.4 Type of device (Type I or II),

12.1.5 Direction of flow through the flame arrester,

12.1.6 Test laboratory and report number,

12.1.7 Lowest MESG of gases for which the flame arrester is suitable,

12.1.8 Ambient air operating temperature range, and

12.1.9 Specification F 1273.

13. Quality Assurance

13.1 Flame arresters shall be designed, manufactured, and tested in a manner that ensures they meet the characteristics of the unit tested in accordance with this specification.

13.2 The flame arrester manufacturer shall maintain the quality of the flame arresters that are designed, tested, and marked in accordance with this specification. At no time shall a flame arrester be sold with Specification F 1273 that does not meet the requirements herein.

14. Keywords

14.1 combustible liquid; flame arrester; flammable liquid; marine technology; ships; tank vent; tank vent flame arrester
INTRODUCTION

This guide provides information on symbols for lifesaving appliances and arrangements required by Chapter III/9.2.3 of the 1983 Amendments to the 1974 Safety of Life at Sea Convention (SOLAS). Though this requirement applies only to ships that have either a SOLAS Passenger Ship Safety Certificate or SOLAS Cargo Ship Safety Equipment Certificate, it is recommended that all vessels or facilities engaged in waterborne operations seriously consider the use of this guide.

1. Scope

1.1 This guide sets forth those symbols to be used to identify the location and operation of lifesaving equipment related to evacuation of personnel in the marine environment.

1.2 The symbols depicted should be used whenever graphic representation could assist personnel in locating their emergency stations and equipment and in the operation of such equipment.

1.3 Posters or signs depicting these symbols should be placed in conspicuous locations in the vicinity of survival craft, their launching controls, or other lifesaving equipment.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 Safety of Life at Sea Convention:2
SOLAS 74 International Convention for the Safety of Life at Sea

3. Significance and Use

3.1 The symbols depicted represent the following:
3.1.1 Equipment required during evacuation or rescue,
3.1.2 Location of muster stations in preparation for evacuation or rescue, or
3.1.3 The sequence of events for operation of survival craft.
3.2 Where station numbers are used with another symbol, they should be abutted to the right hand side of the other symbol.

3.3 Arrows may be used with any other symbol and, where feasible, should point in the direction of the equipment or station by being abutted to the symbol on the edge toward which the arrow is pointing.

3.4 Symbols that indicate station or equipment location should be in white on a green background (see Figs. 1 and 2).

3.5 Symbols that specify the operating sequence of survival craft should be in white on a blue background (see Fig. 3).

3.6 Symbols used as legends in station bills, lifesaving equipment arrangement plans or drawings, or other posters, need not meet the dimensions specified in 3.7.

3.7 Symbols used as markers to indicate the location of stations or equipment should be sized in accordance with 3.7.1 or 3.7.2.

3.7.1 Station number symbol dimensions should be a minimum of 150 mm in height by 75 mm in width (6 by 3 in.).

3.7.1.1 Station number symbol dimensions of 600 by 300 mm (24 by 12 in.) should be used for greater prominence with the larger muster station symbol specified in 3.7.2.1.

3.7.2 Other symbol dimensions should be a minimum of 150 by 150 mm (6 by 6 in.), except:

3.7.2.1 A muster station symbol with dimensions of 600 by 600 mm (24 by 24 in.) may be used in conjunction with the larger station number symbol specified in 3.7.1.1.

3.8 Symbols depicted in Figs. 1 and 2 should represent the survival craft that is actually provided.

4. Illustration of Symbols

4.1 Fig. 1 and Fig. 2 (a through w) are symbols indicating location of emergency equipment and muster and embarkation stations.

4.2 Fig. 3 (a through j) represent the general sequence of events that can be expected during the launching of survival craft. The symbols should reflect the launching procedure recommended by the survival craft or system manufacturer.
5. Keywords

5.1 emergency stations; evacuation equipment; instruction symbols; lifesaving equipment; marine; safety equipment; Safety of Life at Sea Convention; ship; ship evacuation; SOLAS; survival craft; symbols

FIG. 1 Symbols for Location of Emergency Equipment and Muster and Embarkation Stations (continued in Fig. 2)
FIG. 2 Symbols for Location of Emergency Equipment and Muster and Embarkation Stations (continued from Fig. 1)
FIG. 3 Symbols for Launching and Operating Survival Craft

(a) Release Grips

(b) Fasten Seat Belts

(c) Secure Hatches

(d) Start Engine

(e) Start Air Supply

(f) Lower Lifeboat to Water

(g) Lower Liferaft to Water

(h) Lower Rescue Boat to Water

(i) Release Falls

(j) Start Waterspray

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Standard Specification for
Flexible, Expansion-Type Ball Joints for Marine
Applications

This standard is issued under the fixed designation F 1298; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, manufacture, and
testing of ball joints utilized for accommodating thermal
expansion and contraction, or mechanical movement of a
pipeline carrying fluid. The ball joints are intended for use in
systems operating above 0°F (18°C).

1.2 The following precautionary caveat pertains only to the
test methods portion, Section 7, of this specification: This
standard does not purport to address all of the safety concerns,
if any, associated with its use. It is the responsibility of the user
of this standard to establish appropriate safety and health
practices and determine the applicability of regulatory limita-
tions prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 395 Specification for Ferritic Ductile Iron Pressure-
Retaining Castings for Use at Elevated Temperatures
F 722 Specification for Welded Joints for Shipboard Piping
Systems
2.2 ANSI Standard:
B 31.1 Power Piping
2.3 American Society of Mechanical Engineers,
ASME Boiler and Pressure Vessel Code, Section VIII,
Division 1, Pressure Vessels Section IX, Welding and
Brazing Requirements

3. Ordering Information

3.1 Each purchase order or inquiry for ball joints to this
specification shall include the following as applicable:
3.1.1 Title, number, and latest revision of this specification,
3.1.2 Manufacturer’s part number or ball-joint type informa-
tion,
3.1.3 Materials for ball joint and seals, if other than to this
specification,
3.1.4 Service conditions,
3.1.4.1 Minimum and maximum operating temperature
(°F),
3.1.4.2 Maximum operating pressure (psig),
3.1.5 Fluid media (internal),
3.1.6 Atmosphere or media (external),
3.1.7 ANSI pressure class, facing and drilling of flanged
ends, and pipe schedule or wall thickness of ends for weld end
joints,
3.1.8 Special end connections as defined by the purchaser,
3.1.9 Ball sphere or other special coatings, if required,
3.1.10 Qualification test report, if required,
3.1.11 Drawing requirements; for example, envelope drawing
sufficiently detailed to describe the ball joint to be supplied,
and
3.1.12 Other tests to satisfy customer requirements.

4. Materials and Manufacture

4.1 All pressure retaining components shall be fabricated
from wrought or cast steel. Ductile iron complying with
Specification A 395 may be used for the ball joint retaining
ring in services not above 350 psig (2.41 N/mm²) or 450°F
(232°C). Steel shall comply with one of the materials listed in
Section VIII, Division 1, of the ASME Code, or ANSI B 31.1.
4.2 Bolting material shall be in accordance with ANSI
B 31.1.
4.3 Ball spheres shall be coated in accordance with the
manufacturer’s standard practice or as specified by the custom-
er’s specification (see 3.1.9).
4.4 Corrosion shall be considered in the design as set forth
in UG-25 of the ASME Code, Section VIII, Division 1.
4.5 Seals and packing material shall be suitable for the
service intended. This includes being adequate for the pressure
and temperature rating and having sufficient resistance to
attack by the fluid media and atmosphere specified in Section
3.
4.6 Welding procedure qualification, welder performance qualification, and welding materials shall be in accordance with ANSI B 31.1 and Section IX of the ASME Code. Brazing or soldering shall not be used.

5. Other Requirements

5.1 Design:
5.1.1 Ball joints shall be designed to conform to applicable sections of the latest edition of ANSI B 31.1.
5.1.2 Packing—The design for containment of leakage shall be of the manufacturer’s standard design and be qualified by prototype testing of 7.1.

5.2 Pressure and Temperature Rating:
5.2.1 The maximum allowable working pressure (MAWP) and temperature rating for ball joints conforming to this specification shall be established by at least one of the following methods:
5.2.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII, Division 1, of the ASME Code. If burst type tests as outlined in paragraph UG-101(m) are used, it is not necessary to rupture the component which the component was subjected without rupture. Components that have been subjected to a hydrostatic proof test shall not be offered for sale.
5.2.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1, of the ASME Code.
5.2.2 Each ball joint bolting or retainer nut shall be adjusted for proper torque.
5.3 Inlet and outlet connections consisting of welded flanges and fittings shall be in accordance with Specification F 722. When radiography is required (see 8.2), all welds shall be butt welds for Class I piping as required by Specification F 722, except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.

5.4 Where welded construction is used for the fabrication of pressure containing parts, welded joint design details shall be in accordance with Section VIII, Division 1, of the ASME Code and Specification F 722. Except for fillet welds, all welds shall be visually examined in accordance with the requirements prescribed in Section VIII, Division 1, of the ASME Code.

5.5 Inlet and outlet connections consisting of welded flanges and fittings shall be in accordance with Specification F 722. When radiography is required (see 8.2), all welds shall be butt welds for Class I piping as required by Specification F 722, except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.

5.6 Threaded pipe connections shall be limited to the following services:

<table>
<thead>
<tr>
<th>Size</th>
<th>Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 in.</td>
<td>1500 psi</td>
</tr>
<tr>
<td>1 in.</td>
<td>1200 psi</td>
</tr>
<tr>
<td>2 in.</td>
<td>600 psi</td>
</tr>
<tr>
<td>3 in.</td>
<td>400 psi</td>
</tr>
</tbody>
</table>

5.7 Threaded pipe joints above 2 in. (50 mm) NPS shall not be used in systems that require radiographic examination (see 8.2.2).

6. Workmanship, Finish, and Appearance

6.1 Cleaning—The internal and external surfaces of the ball joint shall be cleaned of dirt and other foreign material using a suitable cleaner.

6.2 Surface Preservation—Unless otherwise specified by the purchaser, the ball joint shall be coated in accordance with the manufacturer’s standard practice.

7. Test Methods or Analytical Methods

7.1 Qualification Tests:
7.1.1 A ball joint of each standard design shall be certified as having undergone the following qualification tests. The ball joint shall not show leakage of the test fluid under the conditions of pressurization stipulated in each test.
7.1.1.1 Flex Cycle Test—The ball joint shall be subjected to 8000 flex cycles at MAWP and maximum rated temperature over the rated flex angle. Each flex cycle shall consist of rotating the ball joint from maximum flex angle on one side through $0^\circ$ to maximum flex angle on the other side and return to the original position. The flex cycle rate shall not exceed 4 cpm. At the end of 8000 cycles, MAWP shall be held for at least $\frac{1}{2}$ h.
7.1.1.2 Thermal Cycling—Ball joints rated above 200°F shall be subjected to 100 saturated steam pressure cycles from atmospheric pressure to MAWP and back to atmospheric pressure. Each cycle shall permit the joint to reach saturated steam temperature at MAWP and then cool to ambient temperature. At the end of test, MAWP shall be held for $\frac{1}{2}$ h at saturated steam temperature.

7.2 Production Tests:
7.2.1 Each ball joint shall be subjected to a hydrostatic test conducted at 1½ times the 100°F (38°C) rated maximum allowable working pressure of the ball joint. The test shall be made with water or other fluid having a maximum viscosity of 40 SSU at 125°F (52°C). Minimum duration of test shall be 15 s for ball joints less than 2 in. (50 mm) nominal pipe size, 1 min for ball joints 2½ in. (63.5 mm) through 8 in. (203 mm), and 3 min for larger sizes. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

7.2.1.1 The pressure-containing boundary components of each ball joint may be individually hydrostatically tested provided that an assembled prototype has been subjected to a hydrostatic test as outlined in 7.2.1.
7.2.1.2 The test arrangement shall be air-free prior to pressurization.
7.2.2 Ball joints of 2 in. (50 mm) NPS and smaller with other than flanged connections may, at the option of the manufacturer, be air tested to the lesser of 1.2 times the MAWP or 80 psig (0.55 N/m²). The minimum duration of the test shall be 15 s. Visually detectable leakage through the pressure-retaining walls is not acceptable.

7.2.2.1 If this option is exercised, the manufacturer shall be able to certify that a prototype from each production lot of the same size ball joint was subjected to a hydrostatic test in accordance with 7.2.2.1.

8. Inspection

8.1 Each finished ball joint shall be visually examined and dimensionally checked to ensure it corresponds to this specification.
8.2 Nondestructive Examination of Welds:
8.2.1 All welds shall be visually examined in accordance with ANSI B 31.1.
8.2.2 Welded inlet and outlet connections that are equal to or greater than 4 in. nominal diameter or greater than 0.375 in. nominal wall thickness that are in the following services shall be 100% radiographically examined:

<table>
<thead>
<tr>
<th>Service</th>
<th>Pressure, psig (N/mm²)</th>
<th>Temperature, °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel oil</td>
<td>above 150 (1)</td>
<td>or above 150 (65)</td>
</tr>
<tr>
<td>Steam</td>
<td>above 150 (1)</td>
<td>or above 650 (343)</td>
</tr>
<tr>
<td>Flammable cargo</td>
<td>above 225 (1.55)</td>
<td>or above 150 (65)</td>
</tr>
<tr>
<td>Water</td>
<td>above 225 (1.55)</td>
<td>or above 350 (194)</td>
</tr>
</tbody>
</table>

9. Keywords

9.1 ball joints; marine pipeline; marine technology; ships; thermal contraction; thermal expansion

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Standard Practice for Installation Procedures for Fitting Chocks to Marine Machinery Foundations

This standard is issued under the fixed designation F 1309; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the acceptable methods of fitting chocks to marine machinery foundations.

1.2 The values stated in SI units shall be regarded as standard. The values in parentheses are for information only.

1.3 This standard does not purport to address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

   A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
   D 638 Test Method for Tensile Properties of Plastics
   D 695 Test Method for Compressive Properties of Rigid Plastics

2.2 Other Documents:

   American Bureau of Shipping Rules for Building and Classing Steel Vessels
   American Welding Society Publication, AWS D1.1 Structural Welding Code

3. Significance and Use

3.1 This practice provides the three principal methods of fitting chocks to marine machinery foundations to ensure that the machinery is free of vibration and perfectly aligned after installation.

3.1.1 The three principal methods of installing chocks described herein are as follows:

   3.1.1.1 Type A—Epoxy-based resin, nonshrinking Chockfast Orange PR 610 TCF by Philadelphia Resin Corp., or equal, and
   3.1.1.2 Type B—Two-piece wedge chocks.
   3.1.1.3 Type C—Solid, one-piece fitted chocks.

4. Procedure

4.1 General Requirements for Types A, B, and C Chocking Systems:

4.1.1 Machining:

4.1.1.1 Type A chocks, machinery bedplates, foundation plates, and bolts do not require finish machining if the chocks are not designed to be removed. Unless specified otherwise, Types B and C chock, bolts/studs, machinery bedplate, foundation plates, and fitted holes need to be finished machined and fitted.

4.1.1.2 Surfaces in way of the chock areas on the machinery bedplate and the foundation plate may be machined before installation or while the ship is not waterborne, or both.

4.1.1.3 Unless otherwise specified, all finished surfaces shall be finished to a maximum of 0.003-mm roughness height average (RHA).

4.1.1.4 Finished areas on the machinery bedplate and the foundation plate in way of the chocks shall be sufficiently greater in size than the chock to prevent interference from the unfinished area with the chock during installation.

4.1.1.5 Spotface hole edge radius shall be such that there will not be any interference between it and the bolt head-to-shank radius. The spotface area shall be sufficiently greater in area than that of the bolt head or nut so as not to cause any interference when tightening or with the tooling used. The spotface surfaces shall be perpendicular to the finished fitted hole centerline.

4.1.2 Installation:

4.1.2.1 The ship must be waterborne and fairly well completed before final alignment is accomplished. Ship shall be trimmed as close to the even keel position as practicable. The same trim position shall be maintained throughout the alignment procedure. No heavyweight shall be moved, loaded, or unloaded during alignment; ramps for Ro-Ros shall not be lowered or hoisted.
4.1.2.2 Final machining of the fitted or bearing areas of the machinery bedplate to chock to foundation plate and the mating areas of the fitted portion of the bolt/stud shank and to the hole wall shall be a minimum of 85% uniformly distributed around the mating area. A light coat of Prussian blue shall be used to check the contact areas.

4.1.2.3 Machinery shall be aligned using a sufficient number of jackscrews, shims, and wedges to accommodate adequate up-down, port-starboard, and fore-aft movement without distorting the machinery bedplate or foundation plate and, once aligned, be able to hold that alignment firmly during the final chock installation and bolt-fitting phase.

4.1.2.4 A sufficient number of fitted bolts and chocks shall be installed to maintain the alignment and prevent any relative movement between the machinery and the foundation as a result of vibration and sea state inputs. Number and position of fitted bolts shall comply with the engine manufacturer’s requirements, if any.

4.1.2.5 Bolts shall be installed from the bottom up unless surrounding interferences dictate otherwise.

4.1.2.6 The length of the fitted portion of the bolt/stud shank shall be 95% of the combined thickness between spotfaces of the machinery bedplate, chock, and foundation plate.

4.1.2.7 Final reaming of the fitted bolt holes or machining of the bolt shank shall occur after final alignment.

4.1.2.8 Final torquing of each bolt/nut/stub assembly shall be of sufficient torque to preload the nonfitted portions of the bolt/nut/stub enough to prevent loosening as a result of vibrations, operations, hull, and sea state inputs.

4.1.2.9 Welding shall be performed in accordance with American Bureau of Shipping or the American Welding Society, Structural Code AWS D1.1.

4.1.3 Testing (If Specified):

4.1.3.1 Steel tension tests shall be made in accordance with Test Methods and Definitions A 370.

4.1.3.2 Compression yield and modulus of elasticity tests shall be made in accordance with Test Method D 695.

4.1.3.3 The tensile ultimate test shall be made in accordance with Test Method D 638.

4.1.3.4 The shear ultimate test, the heat distorting temperature test, and the shock resistance test shall be made in accordance with Test Method D 648.

4.2 Type A—Epoxy-based resins are pourable compounds that are poured into properly contained and vented volumes and cure at normal ambient temperatures without shrinkage to form a durable solid.

4.2.1 Provision for Future Machinery Removal—To prevent adhesion of chocks to adjoining surfaces and facilitate future removal of machinery, spray an aerosol release agent on all contact surfaces. This precaution allows these chocks to be removed in a similar manner to steel chocks.

4.2.2 Applicable Techniques:

4.2.2.1 Position dams to retain the compound during pouring and curing without distortion. Damming materials may be expanded plastic, foam rubber stripping and sheet metal, or light gage flat bar. (See Fig. 1.)

4.2.2.2 Follow resin manufacturer’s instructions including the relative design parameters on loading, temperature, allowable thickness, additional design, installation, bolt tension, and inspection.

4.2.3 Foundation Bolts—Install hold-down bolts before pouring of resin. Tension (torque) bolts only after resin manufacturer’s recommended cure time.

4.3 Type B, Two-Piece Wedge Chock—The two-piece wedges are drop-forged, medium steel or machined from steel plate of equal strength or of other materials as specified.

4.3.1 Applicable Techniques—Fig. 2 indicates the configuration of Type C chocks to the machinery bedplate and the foundation plate.

4.3.1.1 The taper on the sloped faces of each half of the chock must not exceed a rise of one over a run of four.

4.3.1.2 Align machinery in place as described in 4.1 and install the lower half of the tapered chock in place with the thicker end in first from the place installation. Ensure it does not move by tack welding. Do not allow distortions or separations.

4.3.1.3 Spotface the upper surface of the machinery bedplate where the finish has not been indicated.

4.3.2 Fitting of Chocks and Bolts—Fig. 3 indicates the fitting of Type B chocks in way of the bedplates and foundation pieces.

4.3.3 Bearing Area—To obtain the 85% bearing area, either measure the spacing between the machine bedplate and the foundation plate at the four corners in way of the proposed chock location and machine the chocks as a unit to fit or, if the lower half of the taper chock is in place, take the same measurement between it and the machinery bedplate in way of the lower half. Machine the upper half to fit and verify the adequacy of the contact area.

4.3.4 Drill holes in the bottom chock piece and foundation plate, either with machinery unit in place or by the marking of holes and lifting the unit clear. Spotface the bottom side of the foundation plate in way of bolt heads.

4.3.5 Fitted Bolts—Fit the bolts/studs to the holes by measuring diameters at 90° to each other in approximately four planes equally spaced through the hole and machine the bolt/stud shank to fit or ream the hole to fit the bolt. Torque the nuts to the proscribed torque.

4.3.6 Excess Length of Chock—Determine the length (with an extra allowance for fitting), and the thickness of the topmost piece of the permanent chock assembly (wedge) at installation. Drill the wedge only after it has been finally fitted in place. Face off the excess length flush with plate edges, and preserve the relative positions of chock parts by tackwelding. For the restrictions and size of the taper see Fig. 3.

4.4 Type C, Solid, One-Piece Fitted Chocks—The chocks are medium steel machined from plate steel consistent with the machinery bedplate and foundation plate and the loads imposed or of other materials as specified.

4.4.1 Applicable Techniques—Fig. 2 indicates the configuration of Type C chocks to the machinery bedplate and the foundation plate.

4.4.2 Align machinery in place as described in 4.1. Do not allow distortions or separations.
4.4.3 *Bearing Area*—To obtain the 85% bearing area, measure the spacing between the machinery bedplate and the foundation plate, measure the gap at the four corners in way of the proposed chock location as indicated in Fig. 2, machine the chock to fit, and verify the adequacy of the bearing area.

4.4.4 *Fitted Bolts*—Fit the bolts/studs to the holes by measuring diameters at 90° to each other in approximately four planes equally spaced through the hole and machine the bolt/stub shank to fit or ream the hole to fit the bolt/stud. Torque the nuts to the proscribed torque.

5. **Keywords**

5.1 chocks; fitting chocks; foundations; installation; machinery foundations, marine; procedures; ship
NOTE: A, B, C&D DIMENSIONS ARE TO BE MACHINED ONTO THE RELATIVE POSITIONS OF THE CHOCK TO OBTAIN PROPER FIT.

FIG. 2 Type C Chock Solid (One Piece)
SUPPLEMENTARY REQUIREMENTS

S1. Scope

S1.1 Supplementary requirements only apply if specified in the contract or purchase order.

S2. Reference Documents

S2.1 Military Document:

MIL-S-901 Shock Tests, H.I. (High Impact); Shipboard, Machinery, Equipment and Systems, Requirements for

Supplementary Test Requirements
S3.1 If specified, shock in accordance with MIL-S-901.

5 Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120–5099, Attn: NPODS.
Standard Specification for Large–Diameter Fabricated Carbon Steel Flanges

This standard is issued under the fixed designation F 1311; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides design and construction criteria for large diameter flanges sizes 14 to 144 NPS, for use in high temperature (1000°F), low pressure service (25 psig), such as internal combustion engine exhaust and forced ventilation systems.

1.2 Values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:
- A 36/A 36M Specification for Carbon Structural Steel
- F 1155 Practice for Selection and Application of Piping System Materials

2.2 American Water Works Association:
- AWWA C 207 Steel Pipe Flanges for Waterwork Service

2.3 Other Documents:
- American Bureau of Shipping Rules for Building and Classing of Steel Vessels, ABS Grade A
- American Welding Society Publication, AWS D 1.1 Structural Welding Code
- Code of Federal Regulations Title 46, Subpart 56.30—10 (b) (5)
- ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Classification

3.1 Type I—Plate flanges, for sizes 14 in. inside diameter up to and including 144 in. inside diameter (see Fig. 1).

3.2 Type II—Rolled angle flanges, for sizes 14 in. up to and including 108 in. inside diameter (see Fig. 1).

4. Ordering Information

4.1 Flanges ordered under this specification shall include the following:
- ASTM designation, title, number, and date of this specification,
- Type and material,
shall apply on flanges of 22 in. nominal pipe size and above.  
identical for both Type I and Type II flanges.

5. Dimensions and Tolerances

5.1 Dimensions—Dimensions shall be in accordance with Table 1.

5.2 Tolerances:
5.2.1 Plus or minus ¼ in. on outside and inside diameters shall apply on flanges of 22 in. nominal pipe size and above. The tolerance for flanges for 20 in. nominal size and below shall be ±⅛ in.
5.2.2 Plus or minus ⅛ in. on bolting circle.

6. Drilling

6.1 Number of holes, hole diameter, and bolt circle are identical for both Type I and Type II flanges.
6.2 Bolt holes shall be equally spaced on the bolt circle.
6.3 Bolt holes provide for ½ in. diameter clearance on bolts.
6.4 Drilling of flanges shall be in accordance with Table 1.

7. Workmanship, Finish, and Appearance

7.1 Flanges manufactured under this specification shall be free of all sharp edges, burrs, projections, weld spatter, and other defects that might be hazardous to personnel or equipment, or both.
7.2 Welding shall be in accordance with the American Bureau of Shipping Rules for Building and Classing of Steel Vessels, ABS Grade A, American Welding Society Publications D 1.1, or ASME Code Section IX.
7.3 Flange faces shall be smooth and free of projections or indentations that would prevent effective gasket seals.
7.4 Flanges when completed shall have no distortion, roundness, or flatness exceeding a tolerance of ±⅛ in.
7.5 The surface finish shall be a minimum of 500 μin. to ensure proper sealing surface for the gasket.
7.6 The material to be used for this specification shall be in accordance with Specification A 36/A 36M, unless prolonged high temperatures will be required; in that case ABS Grade A steel shall be specified in Section 4. For further guidance for selection of materials, see Practice F 1155 and CFR 56.30-10(b)(5).

---

**TABLE 1** Dimensions 1 in. = 25.4 mm 1 lb. = 0.45 kg.

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Inside Diameter, ( C )</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outside Diameter, ( OD )</td>
<td>Thickness, ( T )</td>
<td>Weight in lb.</td>
</tr>
<tr>
<td>14 1/4</td>
<td>21</td>
<td>40</td>
<td>4 x 3</td>
</tr>
<tr>
<td>16 1/4</td>
<td>23 1/4</td>
<td>48</td>
<td>4 x 3</td>
</tr>
<tr>
<td>18 1/4</td>
<td>25</td>
<td>49</td>
<td>4 x 3</td>
</tr>
<tr>
<td>20 1/4</td>
<td>27 1/2</td>
<td>58</td>
<td>5 x 3</td>
</tr>
<tr>
<td>22 1/4</td>
<td>29 1/2</td>
<td>83</td>
<td>5 x 3</td>
</tr>
<tr>
<td>24 1/4</td>
<td>32</td>
<td>97</td>
<td>5 x 3</td>
</tr>
<tr>
<td>26 1/4</td>
<td>34 1/4</td>
<td>108</td>
<td>5 x 3</td>
</tr>
<tr>
<td>28 1/4</td>
<td>36 1/2</td>
<td>119</td>
<td>5 x 3</td>
</tr>
<tr>
<td>30 1/4</td>
<td>38 3/4</td>
<td>131</td>
<td>5 x 3</td>
</tr>
<tr>
<td>32 1/4</td>
<td>41 1/4</td>
<td>176</td>
<td>6 x 4</td>
</tr>
<tr>
<td>34 1/4</td>
<td>43 1/4</td>
<td>186</td>
<td>6 x 4</td>
</tr>
<tr>
<td>36 1/4</td>
<td>46</td>
<td>200</td>
<td>6 x 4</td>
</tr>
<tr>
<td>38 1/4</td>
<td>48 3/4</td>
<td>227</td>
<td>6 x 4</td>
</tr>
<tr>
<td>40 1/4</td>
<td>50 3/4</td>
<td>238</td>
<td>6 x 4</td>
</tr>
<tr>
<td>42 1/4</td>
<td>53</td>
<td>283</td>
<td>6 x 4</td>
</tr>
<tr>
<td>44 1/4</td>
<td>55 3/4</td>
<td>303</td>
<td>6 x 4</td>
</tr>
<tr>
<td>46 1/4</td>
<td>57 3/4</td>
<td>315</td>
<td>6 x 4</td>
</tr>
<tr>
<td>48 1/4</td>
<td>59 3/4</td>
<td>392</td>
<td>6 x 4</td>
</tr>
<tr>
<td>50 5/8</td>
<td>61 3/4</td>
<td>426</td>
<td>6 x 4</td>
</tr>
<tr>
<td>52 5/8</td>
<td>64</td>
<td>452</td>
<td>6 x 4</td>
</tr>
<tr>
<td>54 5/8</td>
<td>66 3/4</td>
<td>478</td>
<td>7 x 4</td>
</tr>
<tr>
<td>56 5/8</td>
<td>68 3/4</td>
<td>505</td>
<td>7 x 4</td>
</tr>
<tr>
<td>58 5/8</td>
<td>70 3/4</td>
<td>533</td>
<td>7 x 4</td>
</tr>
<tr>
<td>60 5/8</td>
<td>73</td>
<td>562</td>
<td>7 x 4</td>
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<tr>
<td>66 3/8</td>
<td>80</td>
<td>666</td>
<td>7 x 4</td>
</tr>
<tr>
<td>72 3/8</td>
<td>86 5/8</td>
<td>750</td>
<td>8 x 4</td>
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<tr>
<td>78 3/8</td>
<td>93</td>
<td>970</td>
<td>8 x 4</td>
</tr>
<tr>
<td>84 3/8</td>
<td>99 3/4</td>
<td>1100</td>
<td>8 x 4</td>
</tr>
<tr>
<td>90 3/8</td>
<td>106 1/4</td>
<td>1230</td>
<td>8 x 4</td>
</tr>
<tr>
<td>96 3/8</td>
<td>113 1/4</td>
<td>1370</td>
<td>9 x 4</td>
</tr>
<tr>
<td>102 1/4</td>
<td>120 1/4</td>
<td>1520</td>
<td>9 x 4</td>
</tr>
<tr>
<td>108 1/4</td>
<td>126 1/4</td>
<td>1670</td>
<td>9 x 4</td>
</tr>
<tr>
<td>114 1/4</td>
<td>133 1/4</td>
<td>1830</td>
<td>9 x 4</td>
</tr>
<tr>
<td>120 1/4</td>
<td>140 1/4</td>
<td>2000</td>
<td>9 x 4</td>
</tr>
<tr>
<td>126 1/4</td>
<td>147 2/0</td>
<td>2500</td>
<td>...</td>
</tr>
<tr>
<td>132 1/4</td>
<td>157 2/0</td>
<td>2710</td>
<td>...</td>
</tr>
<tr>
<td>138 1/4</td>
<td>160 1/2</td>
<td>2930</td>
<td>...</td>
</tr>
<tr>
<td>144 1/4</td>
<td>167 2/0</td>
<td>3150</td>
<td>...</td>
</tr>
</tbody>
</table>

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8. Rejection and Rehearing

8.1 Flanges that fail to conform to the requirements of this specification may be rejected. Rejection may be reported to the producer or the supplier promptly in writing. In case of dissatisfaction with the damaged items, the producer or the supplier may make claim for a rehearing.

9. Certification

9.1 When specified in the purchase order or the contract, the purchaser shall be furnished with certification that samples representing the flanges have been inspected to meet the requirements of this specification. When specified in the purchase order or contract, a report of the results shall be furnished.

10. Packaging and Package Marking

10.1 Flanges shall be marked on the edge of each flange showing the purchase order number, ASTM designation number, material and type, size, and name of manufacturer.

10.2 The flanges shall be packaged in a manner acceptable for shipment by common carrier.

11. Keywords

11.1 carbon steel; flanges; large-diameter flanges; low-pressure service flanges; marine technology; ships
Standard Specification for
Brick, Insulating, High Temperature, Fire Clay¹

1. Scope
1.1 This specification covers one type of thermal insulating brick for use as backup insulation for refractory furnace linings of boiler furnaces.
1.2 The values stated in inch-pound units are to be regarded as standard. The SI units in parentheses are for information purposes only and may be approximate.

2. Referenced Documents
2.1 ASTM Standards:
C 93 Test Methods for Cold Crushing Strength and Modulus of Rupture of Insulating Firebrick²
C 134 Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick³
C 210 Test Method for Reheat Change of Insulating Firebrick³

2.2 Federal Specifications:
PPP-B-601 Boxes, Wood, Cleated-Plywood⁴
PPP-B-621 Boxes, Wood, Nailed and Lock Corner⁴
PPP-B-636 Box, Fireboard⁴

2.3 Military Specifications:
MIL-L-10547 Liners, Case, and Sheet, Overwrap; Vapor-proof or Waterproof, Flexible⁴

2.4 Military Standards:
MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes⁴
MIL-STD-129 Marking for Shipment and Storage⁴

¹ This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.
³ Annual Book of ASTM Standards, Vol 15.01.
⁴ Available from Standardization Documents, Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3. Ordering Information
3.1 Orders for material under this specification shall include the following information as necessary to describe the material adequately:
3.1.1 ASTM designation and year of issue,
3.1.2 Dimensions required (see 6.1), and
3.1.3 Optional requirements, if any (see S1 through S3).

4. Material and Manufacture
4.1 Bricks shall be composed of heat-resistant materials which have been burned or fired to produce the desired density, strength, and structure.

5. Physical and Mechanical Properties
5.1 The average bulk density shall not exceed 45.0 lb/ft³ (720 kg/m³) (see 9.2).
5.2 The modulus of rupture shall average not less than 100 psi (700 kPa) (see 9.3).
5.3 Bricks shall show an average reheat change of not more than 1 % when heated at 2450°F (1343°C) (see 9.4).

6. Dimensions and Permissible Variations
6.1 Insulating brick shall be furnished in the dimensions specified (see 3.1.2). Standard size brick shall be 9 by 4½ by 2½ in. (229 by 114 by 64 mm), 9 by 4½ by 2 in. (229 by 114 by 51 mm), or 9 by 4½ by 1¼ in. (229 by 114 by 32 mm), as specified.
6.2 Standard size brick shall not vary more than ±½ in. (12 mm) from specified dimensions of 2 in. (51 mm) or greater, nor more than ±¼ in. (1 mm) from specified dimensions less than 2 in. (see 9.2).
6.3 For special shapes, no dimension shall vary more than ±1‰ in. (2 mm) from the dimensions specified (see 9.2).
7. Workmanship, Finish, and Appearance

7.1 Bricks shall be of homogeneous structure, free from cracks, laminations, segregations, void defects, or soft centers. All corners and edges shall be sufficiently strong to prevent excessive crumbling or chipping when handled or shipped.

8. Sampling

8.1 For purposes of sampling, an inspection lot for examination and tests shall consist of all material of the same size and shape offered for delivery at one time.

8.2 The sample unit for the tests of Section 9 shall be one brick.

8.3 The sample size (the number of sample units) for the tests of Section 9 shall be as specified in Table 1.

9. Test Methods

9.1 Testing of the End Item—The end item shall be tested for the applicable characteristics as shown on Table 1 from each lot presented for examination for each size and shape of brick.

9.2 Dimensions and Bulk Density—Dimensions and bulk density shall be determined in accordance with the test method specified in Test Methods C 134.

9.3 Modulus of Rupture—The modulus of rupture shall be determined in accordance with the test method specified in Test Methods C 93.

9.4 Reheat Change—The reheat change shall be determined in accordance with Test Method C 210, except that the test specimens shall be maintained at a temperature of 2550°F (1343°C) for 24 h.

10. Inspection

10.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.

11. Product Marking

11.1 Bricks shall be marked with the manufacturer’s name or trademark by suitable indentation or stamping.

12. Packaging

12.1 Bricks shall be packed in containers which will ensure acceptance by common carrier and safe delivery to destination at the lowest applicable rate. Containers shall comply with commercial carrier regulations.

13. Keywords

13.1 brick; insulating brick; fire clay

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the contract or purchase order (see 3.1.3).

S1. Referenced Documents

S1.1 The following documents shall apply only when one or more of the requirements of S2 or S3 are specified in the contract or purchase order (see 3.1.3): Federal Specifications PPP-B-601, PPP-B-621, and PPP-B-636; Military Specification MIL-L-10547; and Military Standards MIL-STD-105, MIL-STD-129, and MIL-STD-147.

S2. Special Government Requirements

S2.1 Examinations and Test Requirements:

S2.1.1 Examination of end item for defects in appearance, workmanship, and dimensions. An examination shall be made in accordance with Tables S1-S4 to determine that the appearance, workmanship, and dimensions of the end item comply with the requirements of this specification.

TABLE 1 Instructions for Testing

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification Reference</th>
<th>Requirements Applicable to</th>
<th>Number of Determinations per Unit</th>
<th>Results Reported as</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pass or Fail</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>5.1</td>
<td>9.2</td>
<td>. . .</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Modulus of rupture</td>
<td>5.2</td>
<td>9.3</td>
<td>. . .</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Reheat change</td>
<td>5.3</td>
<td>9.4</td>
<td>. . .</td>
<td>X</td>
<td>1</td>
</tr>
</tbody>
</table>

*Test reports shall include all values on which average results are based.

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### TABLE S1 Examination of End Item

<table>
<thead>
<tr>
<th>Examine</th>
<th>Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance and workmanship</td>
<td>Material not as specified.</td>
</tr>
<tr>
<td></td>
<td>Not free from cracks, laminations, segregations, and void surface defects.</td>
</tr>
<tr>
<td></td>
<td>Corners or edges chipped or crumbled affecting serviceability.</td>
</tr>
<tr>
<td>Standard brick</td>
<td>Specified dimensions 2 in. (51 mm) or greater vary by more than 1/16 in. (2 mm) from dimension specified.</td>
</tr>
<tr>
<td></td>
<td>Specified dimensions less than 2 in. (51 mm) vary by more than 1/16 in. (1 mm) from dimension specified.</td>
</tr>
<tr>
<td>Special shape brick</td>
<td>Length, width, or thickness varies by more than 1/16 in. (2 mm) from size specified.</td>
</tr>
</tbody>
</table>

### TABLE S2 Examination for Preparation for Delivery

<table>
<thead>
<tr>
<th>Examine</th>
<th>Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packing</td>
<td>Not as specified. Container not as specified, closures not accomplished by specified or required methods or materials. Any nonconforming component, component missing, damaged or otherwise defective, affecting serviceability. Inadequate application of components; such as incomplete closures of case liners, container flaps, loose or inadequate strappings, bulged or distorted containers.</td>
</tr>
<tr>
<td>Count</td>
<td>Number of bricks per container less than specified or indicated quantity.</td>
</tr>
<tr>
<td>Weight</td>
<td>Gross or net weight exceeds specified requirements.</td>
</tr>
<tr>
<td>Markings</td>
<td>Omitted, illegible, incorrect, incomplete, or not as specified.</td>
</tr>
</tbody>
</table>

### TABLE S3 Examination of Palletized Unit Loads

<table>
<thead>
<tr>
<th>Examine</th>
<th>Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packing</td>
<td>Not palletized as specified. Arrangement or number of containers per pallet not in accordance with MIL-STD-147. Inadequate application of components; such as incomplete closures, loose or inadequate strapping, bulged, or distorted containers.</td>
</tr>
<tr>
<td>Count</td>
<td>Less than specified in indicated quantity of containers.</td>
</tr>
<tr>
<td>Markings</td>
<td>Exterior markings omitted, illegible, incorrect, incomplete, or not in accordance with contract requirements</td>
</tr>
</tbody>
</table>

### TABLE S4 Inspection Levels and Acceptable Quality Levels (AQLs) for Examination

<table>
<thead>
<tr>
<th>Examination Paragraph</th>
<th>Inspection Level</th>
<th>AQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2.1.1 (Appearance, workmanship)</td>
<td>S-4</td>
<td>2.5</td>
</tr>
<tr>
<td>S2.1.1 (Dimensions)</td>
<td>S-3</td>
<td>2.5</td>
</tr>
<tr>
<td>S2.1.2</td>
<td>S-2</td>
<td>4.0</td>
</tr>
<tr>
<td>S2.1.3</td>
<td>S-2</td>
<td>4.0</td>
</tr>
</tbody>
</table>

S2.1.1 The sample unit shall be one brick.
S2.1.2 Examination of preparation for delivery. An examination shall be made in accordance with Table S2 and Table S4 to determine that the packing and markings comply with the requirements of Table S3 of this specification.
S2.1.2.1 The sample unit shall be one shipping container, fully packed, selected just before the closing operation.
S2.1.3 Examination of palletized unit loads, as applicable. Unless palletization is not required (see S3.3), an examination in accordance with Table S3 and Table S4 shall be made to determine that palletized unit loads comply with requirements of MIL-STD-147.
S2.1.3.1 The sample unit shall be one palletized load.
S2.1.4 For the test specified in 9.2, the sample size for examination of dimensions shall be governed by S2.1.2.1.
S2.2 The inspection levels for determining the sample size and the acceptable quality levels (AQLs), expressed in defects per 100 units, shall be as specified in Table S4, in accordance with MIL-STD-105.

### S3. Preparation for Delivery

S3.1 Level A—When level A is specified (see 3.1.3), bricks shall be packed in snug-fitting, wood-cleated plywood, nailed wood, or fiberboard boxes conforming to PPP-B-601 (overseas type), or PPP-B-621 (Class 2), or PPP-B-636 (V3c or V3s), respectively. Plywood and nailed wood boxes shall be lined with sealed case liners conforming to MIL-L-10547. Boxes shall be closed and reinforced in accordance with the appendix to the applicable box specification, but wire strapping shall not be used with fiberboard boxes. Crimp-type connectors shall be used with metallic or nonmetallic strapping.
S3.1.1 Each box shall contain not more than the following: 25 Bricks—9 by 4 1/2 by 2 in. (229 by 114 by 51 mm), 40 Bricks—9 by 2 1/2 by 2 1/2 in. (229 by 114 by 64 mm), or 50 Bricks—9 by 1 3/4 by 2 1/2 in. (229 by 114 by 64 mm).
S3.2 Level B—When Level B is specified (see 3.1.3), bricks, in unit quantities specified in S3.1.1, shall be packed in snug-fitting fiberboard boxes conforming to PPP-B-636 (domestic class, grade 200). Boxes shall be closed by Method II and reinforced by use of filament tape, flat steel, or nonmetallic straps in accordance with the appendix to PPP-B-636. Crimp-type connectors shall be used with metallic or nonmetallic strapping.
S3.3 Palletizing—Unless otherwise specified (see 3.1.3), packed brick shall be palletized in accordance with MIL-STD-147. Palletized loads shall be provided with fiberboard caps.
S3.4 Marking—In addition to any special marking required by the contract or purchase order, shipping containers and palletized unit loads shall be marked in accordance with MIL-STD-129. Shipping containers shall be marked as follows: STORE IN DRY PLACE.
Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine the Light Ship Displacement and Centers of Gravity of a Vessel

This standard is issued under the fixed designation F 1321; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reaffirmation. A superscript epsilon (e) indicates an editorial change since the last revision or reaffirmation.

INTRODUCTION

This guide provides the marine industry with a basic understanding of the various aspects of a stability test. It contains procedures for conducting a stability test to ensure that valid results are obtained with maximum precision at a minimal cost to owners, shipyards, and the government. This guide is not intended to instruct a person in the actual calculation of the light ship displacement and centers of gravity, but rather to be a guide to the necessary procedures to be followed to gather accurate data for use in the calculation of the light ship characteristics. A complete understanding of the correct procedures used to perform a stability test is imperative to ensure that the test is conducted properly and so that results can be examined for accuracy as the inclining experiment is conducted. It is recommended that these procedures be used on all vessels and marine craft.

1. Scope

1.1 This guide covers the determination of a vessel’s light ship characteristics. The stability test can be considered to be two separate tasks; the lightweight survey and the inclining experiment. The stability test is required for most vessels upon their completion and after major conversions. It is normally conducted inshore in calm weather conditions and usually requires the vessel be taken out of service to prepare for and conduct the stability test. The three light ship characteristics determined from the stability test for conventional (symmetrical) ships are displacement (displ), longitudinal center of gravity (LCG), and the vertical center of gravity (KG). The transverse center of gravity (TCG) may also be determined for mobile offshore drilling units (MODUs) and other vessels which are asymmetrical about the centerline or whose internal arrangement or outfitting is such that an inherent list may develop from off-center weight. Because of their nature, other special considerations not specifically addressed in this guide may be necessary for some MODUs.

1.2 This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Terminology

2.1 Definitions:

2.1.1 inclining experiment—involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the vessel. By using this information and applying basic naval architecture principles, the vessel’s vertical center of gravity (KG) is determined.

2.1.2 light ship—a vessel in the light ship condition (Condition I) is a vessel complete in all respects, but without consumables, stores, cargo, crew and effects, and without any liquids on board except that machinery fluids, such as lubricants and hydraulics, are at operating levels.

2.1.3 lightweight survey—this task involves taking an audit of all items which must be added, deducted, or relocated on the vessel at the time of the stability test so that the observed condition of the vessel can be adjusted to the light ship condition. The weight, longitudinal, transverse, and vertical location of each item must be accurately determined and recorded. Using this information, the static waterline of the ship at the time of the stability test as determined from measuring the freeboard or verified draft marks of the vessel, the vessel’s hydrostatic data, and the seawater density; the light

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ship displacement and longitudinal center of gravity can be obtained. The transverse center of gravity may also be calculated, if necessary.

3. Significance and Use

3.1 From the light ship characteristics one is able to calculate the stability characteristics of the vessel for all conditions of loading and thereby determine whether the vessel satisfies the applicable stability criteria. Accurate results from a stability test may in some cases determine the future survival of the vessel and its crew, so the accuracy with which the test is conducted cannot be overemphasized. The condition of the vessel and the environment during the test is rarely ideal and consequently, the stability test is infrequently conducted exactly as planned. If the vessel is not 100% complete and the weather is not perfect, there ends up being water or shipyard trash in a tank that was supposed to be clean and dry and so forth, then the person in charge must make immediate decisions as to the acceptability of variances from the plan. A complete understanding of the principles behind the stability test and a knowledge of the factors that affect the results is necessary.

4. Theory

4.1 The Metacenter—(See Fig. 1). The transverse metacenter (M) is based on the hull form of a vessel and is the point around which the vessel’s center of buoyancy (B) swings for small angles of inclination (0 to 4° unless there are abrupt changes in the shape of the hull). The location of B is fixed for any draft, trim, and heel, but it shifts appreciably as heel increases. The location of B shifts off the centerline for small angles of inclination, but its height above the molded keel (K) will stay essentially the same. The height of M trim. The height of about 4°, as the ship is inclined at constant displacement and hand, is essentially fixed over a range of heeling angles up to angles of inclination, but its height above the keel (K) increases. The location of any draft, trim, and heel, but it shifts appreciably as heel changes in the shape of the hull). The location of small angles of inclination (0 to 4° unless there are abrupt

4.2 Metacentric Height—The vertical distance between the center of gravity (G) and M is called the metacentric height (GM). At small angles of heel, GM is equal to the initial slope of the righting arm (GZ) curve and is calculated using the relationship, GZ = GM sin θ. GM is a measure of vessel stability that can be calculated during an inclining experiment. As shown in Fig. 2, moving a weight (W) across the deck a distance (x) will cause a shift in the overall center of gravity (G–G’) of the vessel equal to (W)(x)/displ and parallel to the movement of W. The vessel will heel over to a new equilibrium heel angle where the center of buoyancy (B’) will once again be directly under the center of gravity (G’). Because the angle of inclination during the inclining experiment is small, the shift in G can be approximated by GM tan θ and then equated to (W)(x)/displ. Rearranging this equation slightly results in the following equation:

\[ GM = \frac{(W)(x)}{(\text{displ})(\tan \theta)} \]  

(1)

Since GM and displ remain constant throughout the inclining experiment the ratio (W)(x)/tan θ will be a constant. By carefully planning a series of weight movements, a plot of tangents is made at the appropriate moments. The ratio is measured as the slope of the best represented straight line drawn through the plotted points as shown in Fig. 3, where three angle indicating devices have been used. This line does not necessarily pass through the origin or any other particular point, for no single point is more significant than any other point. A linear regression analysis is often used to fit the straight line.

4.3 Calculating the Height of the Center of Gravity Above the Keel—KM is known for the draft and trim of the vessel during the stability test. The metacentric height (GM), as calculated above, is determined from the inclining experiment. The difference between the height KM and the distance GM is the height of the center of gravity above the keel (KG). See Fig. 4.

4.4 Measuring the Angle of Inclination—(See Fig. 5.) Each time an inclining weight (W) is shifted a distance (x), the vessel will settle to some equilibrium heel angle, θ. To measure this angle (θ) accurately, pendulums or other precise instruments are used on the vessel. When pendulums are used, the two sides
of the triangle defined by the pendulum are measured. \( Y \) is the length of the pendulum wire from the pivot point to the batten and \( Z \) is the distance the wire deflects from the reference position at the point along the pendulum length where transverse deflections are measured. Tangent \( \theta \) is then calculated:

\[
\tan \theta = \frac{Z}{Y}
\]  

(2)

Plotting all of the readings for each of the pendulums during the inclining experiment aids in the discovery of bad readings. Since \((W(x))/\tan \theta\) should be constant, the plotted line should be straight. Deviations from a straight line are an indication that there were other moments acting on the vessel during the inclining. These other moments must be identified, the cause corrected, and the weight movements repeated until a straight line is achieved. Figs. 6-9 illustrate examples of how to detect some of these other moments during the inclining and a recommended solution for each case. For simplicity, only the average of the readings is shown on the inclining plots.

4.5 Free Surface—During the stability test, the inclining of the vessel should result solely from the moving of the inclining weights. It should not be inhibited or exaggerated by unknown moments or the shifting of liquids on board. However, some liquids will be aboard the vessel in slack tanks so a discussion of “free surface” is appropriate.

4.5.1 Standing Water on Deck—Decks should be free of water. Water trapped on deck may shift and pocket in a fashion similar to liquids in a tank.

4.5.2 Tankage During the Inclining—If there are liquids on board the vessel when it is inclined, whether in the bilges or in the tanks, it will shift to the low side when the vessel heels. This shift of liquids will exaggerate the heel of the vessel. Unless the exact weight and distance of liquid shifted can be precisely calculated, the \( GM \) from formula (1) will be in error. Free surface should be minimized by emptying the tanks completely and making sure all bilges are dry or by completely

**FIG. 3 A Typical Incline Plot**

**FIG. 4 Relationship between GM, KM, and KG**

**FIG. 5 Measuring the Angle of Inclination**

**FIG. 6 Excessive Free Liquids**

*NOTE—Recheck all tanks and voids and pump out as necessary; redo all weight movements and recheck freeboard and draft readings.*

**FIG. 7 Port and Starboard Tangents**

**FIG. 8 Relationship between Port and Starboard Moments**

**FIG. 9 Measuring the Angle of Inclination**
filling the tanks so that no shift of liquid is possible. The latter method is not the optimum because air pockets are difficult to remove from between structural members of a tank, and the weight and center of the liquid in a full tank must be accurately determined to adjust the light ship values accordingly. When tanks must be left slack, it is desirable that the sides of the tanks be parallel vertical planes and the tanks be regular in shape (that is, rectangular, trapezoidal, and so forth) when viewed from above, so that the free surface moment of the liquid can be accurately determined. The free surface moment of the liquid in a tank with parallel vertical sides can be readily calculated by the formula:

\[
\text{Free surface (ft}^2\text{tons)} = \frac{1}{12} b^3 Q
\]

where

- \( l \) = length of tank, ft,
- \( b \) = breadth of tank, ft, and
- \( Q \) = specific volume of liquid in tank (ft\(^3\)/ton).

(See Annex A3 for fuel oil conversions or measure \( Q \) directly with a hydrometer.)

Free surface correction is independent of the height of the tank in the ship, location of the tank, and direction of heel.

4.5.3 As the width of the tank increases, the value of free surface moment increases by the third power. The distance available for the liquid to shift is the predominant factor. This is why even the smallest amount of liquid in the bottom of a wide tank or bilge is normally unacceptable and should be removed before the inclining experiment. Insignificant amounts of liquids in V-shaped tanks or voids (for example, a chain locker in the bow), where the potential shift is negligible, may remain if removal of the liquid would be difficult or would cause extensive delays.

5. Preparations for the Stability Test

5.1 General Condition of the Vessel—A vessel should be as complete as possible at the time of the stability test. Schedule the test to minimize the disruption in the vessel’s delivery date or its operational commitments. The amount and type of work left to be completed (weights to be added) affects the accuracy of the light ship characteristics, so good judgment must be used. If the weight or center of gravity of an item to be added cannot be determined with confidence, it is best to conduct the
stability test after the item is added. Temporary material, tool boxes, staging, trash, sand, debris, and so forth on board should be reduced to absolute minimum during the stability test.

5.2 Tankage—Include the anticipated liquid loading for the test in the planning for the test. Preferably, all tanks should be empty and clean or completely full. Keep the number of slack tanks to a minimum. The viscosity of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined.

5.2.1 Slack Tanks:
5.2.1.1 The number of slack tanks should normally be limited to one pair of port and starboard tanks or one centerline tank of the following:
(a) Freshwater reserve feed tanks,
(b) Fuel/diesel oil storage tanks,
(c) Fuel/diesel oil day tanks,
(d) Lube oil tanks,
(e) Sanitary tanks, or
(f) Potable water tanks.
5.2.1.2 To avoid pocketing, slack tanks should normally be of regular (that is, rectangular, trapezoidal, and so forth) cross section and be 20 to 80 % full if they are deep tanks and 40 to 60 % full if they are double-bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the stability test. If the trim changes as the vessel is inclined, then consideration must also be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the vessel is inclined (such as Bunker C at low temperature), should be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks should not be used unless the tanks are heated to reduce viscosity. Communication between tanks should never be allowed. Cross connections, including those via manifolds, should be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross-connection closures.

5.2.2 Pressed Up Tanks—Pressed up means completely full with no voids caused by trim or inadequate venting. Anything less than 100 % full, for example, the 98 % condition regarded as full for operational purposes, is not acceptable. The vessel should be rolled from side to side to eliminate entrapped air before taking the final sounding. Special care should be taken when pressing fuel oil tanks to prevent accidental pollution. An example of a tank that would appear “pressed up,” but actually contained entrapped air is shown in Fig. 10.

5.2.3 Empty Tanks—It is generally not sufficient simply to pump tanks until suction is lost. Enter the tank after pumping to determine if final stripping with portable pumps or by hand is necessary. The exceptions are very narrow tanks or tanks where there is a sharp deadrise, since free surface would be negligible. Since all empty tanks must be inspected, all manholes must be open and the tanks well ventilated and certified as safe for entry. A safe testing device should be on hand to test for sufficient oxygen and minimum toxic levels.

5.3 Mooring Arrangements—The importance of good mooring arrangements cannot be overemphasized. The arrangement selection will be dependent upon many factors. Among the most important are depth of water, wind, and current effects. Whenever possible, the vessel should be moored in a quiet, sheltered area free of extraneous forces such as propeller wash from passing tugs or sudden discharges from shoreside pumps. The depth of water under the hull should be sufficient to ensure that the hull will be entirely free of the bottom. The tide conditions and the trim of the vessel during the test must be considered. Before the test, measure the depth of water and record in as many locations as necessary to ensure the vessel will not contact the bottom. If marginal, conduct the test during high tide or move the vessel to deeper water.

5.3.1 The vessel should be held by lines at the bow and the stern, attached to temporary pad eyes installed as close as possible to the centerline of the vessel and as near the waterline as practical. If temporary pad eyes are not feasible, then lines can be secured to bollards or cleats, or both, on the deck. This arrangement requires that the lines be slackened when the ship is heeled away from the dock. The preferred arrangement is with the vessel lying in a slip where it can be moored as shown in Fig. 11. In this case, the lines can be kept taut to hold the vessel in place, yet allowing unrestricted heeling. Note, however, that wind or current, or both, may cause a superimposed heeling moment to act on the vessel throughout the test. For steady conditions, this will not affect the results. Gusty wind or uniformly varying wind or current, or both, will cause these
superimposed heeling moments to change, which may require additional test points to obtain a valid test. The need for additional test points can be determined by plotting test points as they are obtained.

5.3.2 Where the vessel can be moored to one side only, it is good practice to supplement the bow and stern lines with two spring lines to maintain positive control of the vessel, as shown in Fig. 12. The leads of the spring lines should be as long as practicable. Provide cylindrical camels between the vessel and the dock. All lines should be slack, with the vessel free of the pier and camels, when taking readings.

5.3.2.1 If the vessel is held off the pier by the combined effect of the wind and current, and the bow and stern lines are secured at centerline near the waterline, they can be taut. This is essentially the same as the preferred arrangement described in 5.3.1. As in 5.3.1, varying wind or current, or both, will cause some distortion of the plot.

5.3.2.2 If the vessel is pressed against the camels by wind or current, or both, all lines should be slack. The cylindrical camels will prevent binding, but again there will be an unavoidable superimposed heeling moment as a result of the ship bearing against the camels. This condition should be avoided but when used, give consideration to pulling the ship free of the dock and camels, and letting the ship drift as readings are taken.

5.3.2.3 Another acceptable arrangement is where the combined wind and current are such that the ship may be controlled by only one line at either the bow or the stern. In this case the control line need not be attached near the waterline, but it should be led from on or near the center line of the ship. With all lines but one slack, the ship is free to veer with the wind or current, or both, as readings are taken. This can sometimes be troublesome because varying wind or current, or both, can cause distortion of the plot.

5.3.3 If a floating crane is used for handling inclining weights it should not be moored to the ship.

5.3.4 Remove the access ramps. Power lines, hoses, and so forth connected to shore should be at a minimum and kept slack at all times.

5.4 List and Trim—To simplify calculations the vessel should be as close as possible to even list and design trim and have sufficient draft so that any abrupt changes in the waterplane will be avoided as the ship is inclined from side to side. If the vessel has a bow appendage, such as a bulbous bow or sonar dome, hard chine, or transom stern at the waterline, then give consideration to changing the draft or trim to ensure there is a minimum change in the waterplane area as the vessel is heeled from side to side. Trim different from design of up to 1% of LBP (length between perpendiculars) is normally acceptable when using hydrostatic data calculated at design trim. Exercise caution when applying the “1 % rule of thumb” to ensure that excessive error, as would result from a significant change in the waterplane area during heeling, is not introduced into the stability calculations. With inclining weights in the initial position, up to 1/2° of list is acceptable. If the list exceeds this, use leveling weights to put the vessel in an acceptable condition.

5.5 Test Weights—The total weight used should be sufficient to provide a minimum inclination of 1° and a maximum of 4° of heel.

5.5.1 One approach that can be taken to estimate how much weight is needed follows:

5.5.1.1 Measure the maximum athwartships distance (x) that is available on deck to shift the weights as shown in Fig. 13. 5.5.1.2 Estimate the draft the vessel will be at for the stability test and find the corresponding displacement from the vessel’s hydrostatic data.

5.5.1.3 Estimate the GM of the vessel by estimating its center of gravity (KG) and subtracting that value from KM, obtained from the hydrostatic data for the appropriate draft;

\[ GM = KM - KG \]  

5.5.1.4 Estimate the total weight (W) required by the following formula:

\[ W = \frac{GM \cdot (\tan \theta \cdot \text{displ})}{x} \]

where \( \theta \) is the desired angle of inclination between 1 and 4°. 5.5.1.5 It would be prudent to have additional weights readily available to compensate for any inaccurate estimates.

5.5.2 Test weights should be compact and of such a configuration that the KG (vertical center of gravity) of the weights can be accurately determined. Weights, such as porous concrete, that can absorb significant amounts of moisture, should only be used if they were weighed just before the stability test or if recent weight certificates are presented. Mark each weight with an identification number and weight. For small vessels, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control.

5.5.2.1 Certify test weights using a certificated scale. Perform the weighing close enough in time to the stability test to ensure that the measured weight is accurate. The time since weighing depends on the construction of the weight.

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![FIG. 12 An Acceptable Alternate Mooring Arrangement](image1)

![FIG. 13 Movement of the Test Weights](image2)
5.5.3 A crane of sufficient capacity and reach, or some other means, must be available during the stability test to shift weights on the deck in an expeditious and safe manner.

5.5.4 Take precautions to ensure that the decks are not overloaded during weight movements. If deck strength is questionable, then perform a structural analysis to determine if existing framing can support the weight.

5.5.5 The test weights should be on board and in place before the scheduled time of the stability test.

5.6 **Pendulums:**

5.6.1 Use a minimum of three pendulums to allow identification of bad readings at any one pendulum station. They should each be located in an area protected from the wind. If this is not possible, then erect a screen around the exposed portions of the pendulums. Good locations for pendulums are ladder trunks, elevator shafts, hatchways, or any access way passing through decks.

5.6.2 The pendulums should be long enough to give a measured deflection, to each side of upright, of at least 6 in. Generally, this will require a pendulum length of at least 10 ft. Usually, the longer the pendulum the greater the accuracy of the test; however, if excessively long pendulums are used on a tender ship, the pendulums may not settle down and the accuracy of the pendulums would then be questionable. On smaller vessels, where there is insufficient headroom to hang long pendulums, obtain the 6-in. deflection by increasing the test weight so as to increase the list. The typical inclination is between 2 and 3° but in no case should the maximum angle of list be greater than 4°. As shown in Fig. 14, the pendulums must be at least 87 in. long to get at least 6 in. of deflection without exceeding the 4° maximum heel.

5.6.3 If the pendulums are of different lengths, the possibility of collusion between station recorders is avoided. The pendulum wire should be piano wire or other monofilament material. The top connection of the pendulum should afford unrestricted rotation of the pivot point. An example is that of a washer with the pendulum wire attached suspended from a nail.

5.6.4 Provide a trough filled with a thick oil to dampen oscillations of the pendulum after each weight movement. It should be deep enough to prevent the pendulum weight from touching the bottom.

5.6.5 The use of a winged plumb bob at the end of the pendulum wire can also help to dampen the pendulum oscillations in the oil.

5.6.6 The battens should be smooth, light-colored wood, ½ to ¾ in. thick, and should be securely fixed in position so that an inadvertent contact will not cause them to shift. The batten should be aligned close to the pendulum wire but not in contact with it.

5.6.7 The pendulums should be in place before the scheduled time of the stability test.

5.6.8 A typical satisfactory arrangement is shown in Fig. 15. The pendulums may be placed in any location on the vessel, longitudinally and transversely.

5.6.9 If the person conducting the test desires to substitute inclinometers or other measuring devices for the pendulums, complete prior testing of the measuring devices to verify their accuracy before actual substitution for the pendulums. It is recommended that the inclinometers or other measuring devices be used in conjunction with the pendulums instead of using only other devices and no pendulums.

5.7 **Communications Arrangements:**

5.7.1 One person at a central control station should have complete control over all personnel involved in the test.
5.7.2 There should be efficient two-way communications between central control and the weight handlers and between central control and each pendulum station.
5.7.3 Shelter the central control station from the elements, and have adequate lighting so that a plot of tangents versus heeling moments can be made during the test. It is desirable that the weight handlers be directly observed from the control station.
5.8 Additional Requirements:
5.8.1 Annex A1 contains additional requirements that must be met, if U.S. Coast Guard approval of the stability test is needed.
5.8.2 Annex A2 contains additional requirements that must be met for stability tests on U.S. Navy vessels.

6. Plans and Equipment Required
6.1 Plans—The person in charge of the inclining should have available a copy of the following at the time of the stability test:
   6.1.1 Lines plan,
   6.1.2 Curves of form (hydrostatic curves) or hydrostatic data,
   6.1.3 General arrangement plan of decks, holds, inner bottoms, and so forth,
   6.1.4 Outboard profile,
   6.1.5 Inboard profile,
   6.1.6 Midship section,
   6.1.7 Capacity plan showing capacities and vertical and longitudinal centers of gravity of cargo spaces, tanks, and so forth,
   6.1.8 Tank sounding tables,
   6.1.9 Draft mark locations, and
   6.1.10 Docking drawing with keel profile and draft mark corrections (if available).
6.2 Equipment—Besides the physical equipment necessary such as the inclining weights, pendulums, small boat, and so forth, the following are necessary and should be provided by or made available to the person in charge of the inclining:
   6.2.1 Three engineering scales for measuring pendulum deflections (rules should be subdivided into at least tenths of an inch),
   6.2.2 Three sharp pencils for marking pendulum deflections,
   6.2.3 Chalk for marking the various positions of the inclining weights,
   6.2.4 A sufficiently long measuring tape for measuring the movement of the weights and locating different items on board,
   6.2.5 A sufficiently long sounding tape for sounding tanks and taking freeboard readings,
   6.2.6 One or more specific gravity hydrometers, either 60°F/15°C (ASTM 125) or other, with range sufficient to cover 0.999 to 1.030, to measure the specific gravity of the water in which the vessel is floating (a quality hydrometer for measuring specific gravity of less than 1.000 may be needed in some locations),
   6.2.7 Other hydrometers as necessary to measure the specific gravity of any liquids on board,
   6.2.8 Graph paper to plot inclining moments versus tangents,
   6.2.9 A straight edge to draw the measured waterline on the lines drawing,
   6.2.10 A pad of paper to record data,
   6.2.11 An explosion proof testing device to check for sufficient oxygen and absence of lethal gases in tanks and other closed spaces such as voids and cofferdams,
   6.2.12 A thermometer, and
   6.2.13 Draft tubes (if necessary).

7. Procedure
7.1 The inclining experiment, the freeboard/draft readings, and the survey, may be conducted in any order and still achieve the same results. If the person conducting the stability test is confident that the survey will show that the vessel is in an acceptable condition and there is the possibility of the weather becoming unfavorable, then it is suggested that the inclining be performed first and the survey last. If the person conducting the test is doubtful that the vessel is complete enough for the test, it is recommended that the survey be performed first since this could invalidate the entire test, regardless of the weather conditions. It is very important that all weights, the number of people on board, and so forth, remain constant throughout the test. Appendix X1 contains a stability test check list that can be used to make a quick check that the procedure is correctly followed.

7.1.1 Initial Walk Through and Survey—The person responsible for conducting the stability test should arrive on board the vessel well in advance of the scheduled time of the test to ensure that the vessel is properly prepared for the test. If the ship to be inclined is large, a preliminary walk-through may need to be done the day preceding the actual incline. To ensure the safety of personnel conducting the walk-through, and to improve the documentation of surveyed weights and deficiencies, at least two persons should make the initial walk-through. Things to check include: all compartments are open, clean, and dry, tanks are well ventilated and gas free; movable or suspended items are secured and their position documented; pendulums are in place; weights are on board and in place; a crane or other method for moving weights is available; and the necessary plans and equipment are available. Before beginning the stability test, the person conducting the test should:

7.1.1.1 Consider the weather conditions. The combined adverse effect of wind, current, and sea may result in difficulties or even an invalid test due to the following:
   (a) Inability to record freeboards and drafts accurately,
   (b) Excessive or irregular oscillations of the pendulums, and
   (c) Variations in unavoidable superimposed heeling moments.
In some instances, unless conditions can be sufficiently improved by moving the vessel to a better location, it may be necessary to delay or postpone the test. Any significant quantities of rain, snow, or ice must be removed from the vessel before the test.

7.1.1.2 Make a quick overall survey of the vessel to make sure the vessel is complete enough to conduct the test and to ensure that all equipment is in place.

7.1.1.3 Enter all empty tanks after it is determined that they are well ventilated and gas free to ensure that they are dry and
free of debris. Ensure that any pressed up tanks are indeed full and free of air pockets.

7.1.1.4 Survey the entire vessel to identify all items that need to be added to the vessel, removed from the vessel, or relocated on the vessel to bring the vessel to the light ship condition. Each item must be clearly identified by weight and vertical and longitudinal location. If necessary, record also the transverse location. The inclining weights, the pendulums, any temporary equipment and dunnage, and the people on board during the stability test are all among the weights to be removed to obtain the light ship condition. The person calculating the light ship characteristics from the data gathered during the incline and survey or the person reviewing the stability test, or both, may not have been present during the test and must be able to determine the exact location of the items from the data recorded and the vessel’s drawings. Any tanks containing liquids must be accurately sounded and the soundings recorded. Table 1 is an example of just a few typical entries from a survey.

(a) It is recognized that the weight of some items on board, or that are to be added, may have to be estimated. If this is necessary, it is in the best interest of safety to be on the safe side when estimating, so the following rules of thumb should be followed:

(1) When estimating weights to be added:
   – estimate high for items to be added high in the vessel, and
   – estimate low for items to be added low in the vessel.

(2) When estimating weights to be removed:
   – estimate low for items to be removed from high in the vessel, and
   – estimate high for items to be removed from low in the vessel.

7.1.2 Freeboard/Draft Readings:

7.1.2.1 Take freeboard/draft readings to establish the position of the waterline to determine the displacement of the vessel at the time of the stability test. It is recommended that at least five freeboard readings, approximately equally spaced, be taken on each side of the vessel or that all draft marks (forward, midship, and aft) be read on each side of the vessel. Take draft mark readings to assist in determining the waterline defined by freeboard readings or to verify the vertical location of draft marks on vessels where their location has not been confirmed. The locations for each freeboard reading should be clearly marked. The longitudinal location along the vessel must be accurately determined and recorded since the (molded) depth at each point will be obtained from the vessel’s lines. All freeboard measurements should include a reference note clarifying the inclusion of the coaming in the measurement and the coaming height.

7.1.2.2 Read draft and freeboard readings immediately before or immediately after the inclining test. Weights must be on board and in place and all personnel who will be on board during the test including those who will be stationed to read the pendulums should be on board and in location during these readings. This is particularly important on small vessels. If readings are made after the test, maintain the vessel in the same condition as during the test. For small vessels, it may be

<table>
<thead>
<tr>
<th>TABLE 1 Typical Survey Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Items To Be Removed</strong></td>
</tr>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Inclining Weight No. 1</td>
</tr>
<tr>
<td>Inclining Weight No. 2</td>
</tr>
<tr>
<td>Inclining Weight No. 3</td>
</tr>
<tr>
<td>Inclining Weight No. 4</td>
</tr>
<tr>
<td>Two men</td>
</tr>
<tr>
<td>Two men</td>
</tr>
<tr>
<td>Pendulum No. 1 (total setup and one man)</td>
</tr>
<tr>
<td>Fuel oil tank No. 3P 8 ft 8 in. sounding</td>
</tr>
<tr>
<td>Potable water tk No. 1C 9 ft 3 in. sounding</td>
</tr>
</tbody>
</table>

<p>| <strong>Items To Be Added</strong>          |</p>
<table>
<thead>
<tr>
<th><strong>Item</strong></th>
<th><strong>Weight, lb</strong></th>
<th><strong>Vertical Center</strong></th>
<th><strong>Longitudinal Center</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>200</td>
<td>5 ft above pilot deck</td>
<td>2 ft aft forward pilot house bulkhead</td>
</tr>
<tr>
<td>Antenna</td>
<td>85</td>
<td>15 ft above top of pilot house</td>
<td>frame 20</td>
</tr>
<tr>
<td>Towing cable</td>
<td>800</td>
<td>2.5 ft above main deck</td>
<td>8 ft forward frame 85</td>
</tr>
<tr>
<td>Rescue boat</td>
<td>120</td>
<td>4 ft above main deck</td>
<td>frame 60</td>
</tr>
</tbody>
</table>

<p>| <strong>Items To Be Relocated</strong>      |</p>
<table>
<thead>
<tr>
<th><strong>Item</strong></th>
<th><strong>Weight, lb</strong></th>
<th><strong>Vertical</strong></th>
<th><strong>Longitudinal</strong></th>
<th><strong>To</strong></th>
<th><strong>Vertical</strong></th>
<th><strong>Longitudinal</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Liferaft</td>
<td>300</td>
<td>main deck</td>
<td>frame 50</td>
<td>01 deck</td>
<td>frame 65</td>
<td></td>
</tr>
<tr>
<td>Fire pump</td>
<td>220</td>
<td>main deck</td>
<td>frame 65</td>
<td>2 ft above shell</td>
<td>frame 40</td>
<td></td>
</tr>
</tbody>
</table>

\(^a^Can be determined later by the naval architect from drawings or sounding tables, or both.
necessary to counterbalance the list and trim effects of the freeboard measuring party. When possible, take readings from a small boat.

7.1.2.3 The mooring lines should be slack such that the vessel floats freely. A check should be made that the vessel is not resting on the bottom.

7.1.2.4 Determine the specific gravity of the flotation water at this time. Take samples from a sufficient depth of the water to ensure a true representation of the flotation water and not merely surface water, which could contain fresh water from run off of rain. Place a hydrometer in a water sample and read and record the specific gravity. For large vessels, it is recommended that samples of the flotation water be taken forward, midship, and aft and the readings averaged. For small vessels, one sample taken from midships should be sufficient. A conversion table from specific gravity to specific volume is contained in Annex A3. Take the temperature of the water and correct the measured specific gravity for deviation from the standard, if necessary. A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when sample temperature differs from the temperature at the time of the inclining (for example, if check of specific gravity is done at the office).

7.1.2.5 A small boat should be available to aid in the taking of freeboard and draft mark readings. It should have low freeboard to permit accurate observation of the readings.

7.1.2.6 A draft mark reading may be substituted for a given freeboard reading at that longitudinal location if the height and location of the mark has been verified to be accurate by a keel survey while the vessel was in drydock.

7.1.2.7 A device, such as a draft tube, can be used to improve the accuracy of freeboard/draft readings by damping out wave action.

7.1.2.8 The dimensions given on a vessel’s lines drawing are normally molded dimensions. In the case of depth (D), this means the distance from the inside of the bottom shell to the inside of the deck plate. To plot the vessel’s waterline on the lines drawing, convert the freeboard readings to molded drafts (d). See Fig. 16. If the freeboard is measured from the main deck to the waterline:

\[ d = D + t - f \] (6)

See Fig. 17. If the freeboard is measured from the top of the bulwark to the waterline:

\[ d = D + t + b - f \] (7)

Similarly, correct the draft mark readings from extreme (bottom of keel) to molded (top of keel) before plotting. Resolve any discrepancy between the freeboard/draft readings.

7.1.2.9 Calculate the mean draft (average of port and starboard reading) for each of the locations where freeboard/draft readings are taken and plotted on the vessel’s lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot should yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, retake the freeboards/drafts.

7.1.3 The Inclining Experiment:

7.1.3.1 Before any weight movements, check the following:
(a) Check the mooring arrangement to ensure that the vessel is floating freely. (Do this just before each reading of the pendulums.)

(b) Measure the pendulums and record their lengths. The pendulums should be aligned so that when the vessel heels, the wire will be close enough to the batten to ensure an accurate reading but will not come into contact with the batten. The typical satisfactory arrangement is shown in Fig. 15.

(c) Mark the initial position of the weights on the deck. This can be done by tracing the outline of the weights on the deck.

(d) The communications arrangement is adequate.
(e) All personnel are in place.

7.1.3.2 Run a plot during the test to ensure that acceptable data is being obtained. Typically, the abscissa of the plot will be heeling moment (weight times distance) and the ordinate will be the tangent of the heel angle (deflection of the pendulum divided by the length of the pendulum).

7.1.3.3 The standard test uses eight weight movements. Movement No. 8, a recheck of the zero point, may be omitted if a straight line plot is achieved after Movement No. 7.

7.1.3.4 The weight movements shown in Fig. 18 give a good spread of points on the test plot.

7.1.3.5 Once everything and everyone is in place, obtain the zero position and conduct the remainder of the experiment as quickly as possible, while maintaining accuracy and proper procedures, to minimize the possibility of a change in environmental conditions during the test.

7.1.3.6 Before each pendulum reading, each pendulum station should report to the control station when the pendulum has stopped swinging. Then, the control station will give a “standby” warning and then a “mark” command. When “mark” is given, the batten at each position must be marked at the location of the pendulum wire. If the wire was oscillating slightly, take the center of the oscillations as the mark. If any of the pendulum readers does not think the reading was a good one, the reader should advise the control station and the point should be retaken for all pendulum stations. Likewise, if the control station suspects the accuracy of a reading, it should be repeated for all the pendulum stations. Next to the mark on the batten should be written the number of the weight movement, such as zero for the initial position and one through seven for the weight movements.

7.1.3.7 Make each weight movement in the same direction, normally transversely, so as not to change the trim of the vessel. After each weight movement, measure the distance the weight was moved (center to center) and calculate the heeling moment by multiplying the distance by the amount of weight moved. Calculate the tangent for each pendulum by dividing the deflection by the length of the pendulum. Plot the three resultant tangents on the graph. Provided there is good agreement among the pendulums with regard to the tan θ value, the average of the three pendulum readings may be graphed instead of plotting each of the readings.

7.1.3.8 If a straight line plot is achieved after the initial zero and six weight movements, the stability test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did not yield acceptable plotted points must be repeated or explained.

8. Report

8.1 Appendix X2 contains sample data sheets to record data during stability tests. It is suggested that these sheets be used so that no data is forgotten and so that the data is clear, concise, and consistent in form and format.

8.2 Appendix X3 contains sample sheets to aid in calculating the results of the stability test.

8.3 Alternatively, all calculations performed during the inclining and in preparation of the report may be carried out by a suitable computer program. Output generated by such a program may be used for presentation of all or partial data and calculations included in the test report if it is clear, concise, well documented, and generally consistent in form and content with the forms in Appendixes X2 and X3.

8.4 Annex A3 contains conversion factors to be used in changing specific gravity of fuel oil and water to specific volume.

9. Precision and Bias

9.1 The accuracy of the stability test is directly related to the accuracy of the measuring conditions at the time of the test. Many factors can influence the reliability of the information gained. The weather, the vessel loading, the mooring arrangements, the state of completion of the vessel, and so forth, can all significantly affect the final results of the test. Conditions during the measurement period should be such that readings can be recorded and then repeated to give consistent data. Make the required measurements, attempting to reach the following precision:

- Freeboards nearest 1⁄8 in.
- Draft marks nearest 1⁄8 in.
- Pendulum lengths nearest 1⁄6 in. (0.05 in. on a 1⁄10-in. scale)
- Survey weights 1 % of the weight (5 % for small items)
- Tank soundings nearest 1⁄8 in.

The precision used to read measurements does not guarantee the resulting overall accuracy of the test. If all procedures in this guide are followed, the test results should have satisfactory accuracy.
A1. Prior Notification To The Coast Guard Marine Safety Center—Written notification of the test must be sent to the Coast Guard Marine Safety Center (MSC) at least two weeks before the test. The MSC will make arrangements for an acceptable representative to witness the test.

A1.1 Details of Notification
Written notification should provide the following information:
A1.1.1 Identification of the vessel by name and shipyard hull number, if applicable.
A1.1.2 Date, time, and location of the test.
A1.1.3 Inclining weight data.
   (a) Type,
   (b) Amount (number of units and weight of each),
   (c) Certification,
   (d) Method of handling (that is, sliding rail or crane), and
   (e) Anticipated maximum angle of heel to each side.
A1.1.4 Pendulums
   Approximate location and length. (If a shipyard/naval architect desires to substitute inclinometers or other measuring devices for one or two of the three required pendulums, prior approval must be obtained from the MSC. The MSC might require that the devices be used in addition to the pendulums on one or more inclinings to verify their accuracy before allowing actual substitution for a pendulum.)
A1.1.5 Approximate trim.
A1.1.6 Condition of tanks.
A1.1.7 Estimated weights to deduct, to complete, and to relocate to place the vessel in its true light ship condition.
A1.1.8 Detailed description of any computer software to be used to aid in calculations during the inclining.
A1.1.9 Name and phone number of the person responsible for conducting the test.

A1.2 Alternate mooring arrangements will be considered if submitted for review before the test. Such arrangements should ensure that the vessel will be free to list without restraint for a sufficient period of time to allow the pendulums to damp out motion so that the readings can be recorded.

A1.3 Each of the test weights must be certified by a weigh master’s document and a copy provided to the Coast Guard representative. For small vessels, capped drums, completely filled with water, may be used. In such cases, the weight should be verified in the presence of the Coast Guard representative using a recently calibrated scale.

A1.4 If bad weather conditions are detected early enough and the weather forecast does not call for improving conditions, the Coast Guard representative should be advised before departure from the office and an alternate date scheduled.

A1.5 An estimate of work items that will be outstanding at the time of the stability test should be included as part of any test procedure submitted to the MSC. This is required so that the Coast Guard representative can advise the shipyard/naval architect if in their opinion the vessel will not be sufficiently complete to conduct the stability test and that it should be rescheduled. If the condition of the vessel is not accurately depicted in the test procedure and at the time of the stability test the Coast Guard witness considers that the vessel is in such condition that an accurate stability test cannot be conducted, the witness may refuse to accept the test and require that a test be conducted at a later date.

A1.6 A certified marine chemist’s certificate certifying that all fuel oil and chemical tanks are safe for human entry should be available, if necessary.

A1.7 If a computer program is used to perform calculations during the inclining, Coast Guard approval to use the program must be obtained prior to the test.

A1.8 Before departing the vessel, the person conducting the test and the Coast Guard representative should initial each sheet as an indication of their concurrence with the recorded data.

A1.9 A copy of the data should be forwarded to the MSC along with the stability test report.

A1.10 When completed, three copies of the stability test report should be submitted to the MSC for approval.

A1.11 The Coast Guard may alter or limit acceptance of any provision in this guide.

A1.12 When the American Bureau of Shipping is representing the Coast Guard during a stability test, the words, American Bureau of Shipping, should be substituted for the words, Coast Guard, and for the words, Marine Safety Center, in this annex.
A2. FOR STABILITY TESTS ON UNITED STATES NAVY (USN) VESSELS THE FOLLOWING ADDITIONAL REQUIREMENTS APPLY

A2.1 The inclining experiment shall be performed in accordance with the requirements set forth in Naval Ship’s Technical Manual, and as modified below. The stability test report shall be prepared on the forms described in the above technical manual.

A2.2 Photographs of topside arrangements including weather decks is required to document topside installations. Photographs of each draft mark reading are also required.

A2.3 A comprehensive survey of all compartments, tanks, and voids is required to determine the weight and center of gravity (vertical, longitudinal, and transverse) of all consumable loads, including personnel, ammunition, provisions, general stores, and liquids.

A2.4 Draft readings are required. Amidships marks should be read to determine hog or sag of ship. Projection draft marks and freeboard readings can be used to verify accuracy of draft mark readings.

A2.5 Inclining weights are moved transversely to produce at least two inclinations to port and two to starboard.

A2.6 Significant items of weight that are considered part of the lightship displacement but are subject to change or are readily removable are listed, as part of the report, by weight and center of gravity. These items include boats, armament, ballast, salvage gear, and yellow gear.

A2.7 It is desirable under most circumstances to incline the vessel at design trim. If however, the area of the waterplane will change substantially as the ship is heeled from side to side, then the trim should be altered, to minimize the change in the waterplane area during the incline. This may require that functions of wedges be calculated to correct for the trimmed conditions. The hydrostatics must be verified or recalculated, or both, if the as-trimmed waterplane area differs from the waterplane area at the design trim.

A2.8 The freeboard/draft mark readings must be taken simultaneously on both sides of the vessel, to ensure that any heel is properly recorded at the time of the stability test.

A2.9 The transverse center of gravity (TCG) must be determined for all ships.

A2.10 In presentation of incline results, incline plots are to be arranged such that the slope of the incline plot can be directly substituted into the \( GM \) formula as shown below.

\[
GM = \frac{\text{slope}}{\text{displ}}
\]

where slope of the line from the incline plot equals the (rise/run). Heeling moments must be on the ordinate and tangents must be on the abscissa. Fig. A2.1 gives an example of an acceptable plot.

\[2 \text{ NAVSEA 59086-C6-STM-000, Chapter 096, “Weights and Stability,” available from Commanding Officer, Naval Ships Weapon System Engineering Station, Code 5700, Port Hueneme, CA 93043.}\]
A3. CONVERSION TABLES FOR LIQUIDS

A3.1 Table A3.1 and Table A3.2 are based on the weight of 1 gal of water in air against brass weights at 60°F and 30-in. mercury at 45° latitude at sea level and 50% humidity. They were taken from the National Bureau of Standards Circular C-410.3

3 Available from National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

### TABLE A3.1 Fuel Oil

<table>
<thead>
<tr>
<th>Degrees</th>
<th>Specification Gravity</th>
<th>bbl/ton</th>
<th>ft³/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.0000</td>
<td>6.404</td>
<td>35.96</td>
</tr>
<tr>
<td>11</td>
<td>0.9930</td>
<td>6.449</td>
<td>36.21</td>
</tr>
<tr>
<td>12</td>
<td>0.9861</td>
<td>6.494</td>
<td>36.46</td>
</tr>
<tr>
<td>13</td>
<td>0.9792</td>
<td>6.540</td>
<td>36.72</td>
</tr>
<tr>
<td>14</td>
<td>0.9725</td>
<td>6.585</td>
<td>36.97</td>
</tr>
<tr>
<td>15</td>
<td>0.9659</td>
<td>6.630</td>
<td>37.22</td>
</tr>
<tr>
<td>16</td>
<td>0.9593</td>
<td>6.676</td>
<td>37.48</td>
</tr>
<tr>
<td>17</td>
<td>0.9529</td>
<td>6.720</td>
<td>37.73</td>
</tr>
<tr>
<td>18</td>
<td>0.9465</td>
<td>6.766</td>
<td>37.99</td>
</tr>
<tr>
<td>19</td>
<td>0.9402</td>
<td>6.811</td>
<td>38.24</td>
</tr>
<tr>
<td>20</td>
<td>0.9340</td>
<td>6.856</td>
<td>38.50</td>
</tr>
<tr>
<td>21</td>
<td>0.9279</td>
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<td>38.75</td>
</tr>
<tr>
<td>22</td>
<td>0.9218</td>
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<td>23</td>
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</tr>
<tr>
<td>24</td>
<td>0.9100</td>
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<tr>
<td>26</td>
<td>0.8984</td>
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<td>27</td>
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<td>28</td>
<td>0.8871</td>
<td>7.219</td>
<td>40.53</td>
</tr>
<tr>
<td>29</td>
<td>0.8816</td>
<td>7.264</td>
<td>40.78</td>
</tr>
<tr>
<td>30</td>
<td>0.8762</td>
<td>7.309</td>
<td>41.04</td>
</tr>
</tbody>
</table>

**Conversion formula:**

Specific gravity = \( \frac{141.5}{(131.5 + B)} \)

where \( B \) = degrees API.

### TABLE A3.2 Water

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>ft³/ton</th>
</tr>
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<tbody>
<tr>
<td>0.999</td>
<td>35.99</td>
</tr>
<tr>
<td>1.000</td>
<td>35.96</td>
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<td>1.001</td>
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<td>1.027</td>
<td>35.01</td>
</tr>
<tr>
<td>1.028</td>
<td>34.98</td>
</tr>
</tbody>
</table>
X1.1 Pre-Inclining:

1.________Vessel is complete or nearly so.
   (a) No major structural sections or major items of equip-
   ment to be added or removed.
   (b) No tanks with liquids not shown in the inclining
   procedure.
   (c) No extraneous gear and personnel on board the vessel.
2.________ Weather conditions are satisfactory.
   (a) No gusting winds. Steady light wind not causing
   motions is acceptable. Beam winds to be avoided. Wind speed
   normally acceptable if draft marks can be read.
   (b) No strong currents.
   (c) Not raining.
   (d) No waves. Ripples acceptable if can read freeboards to
   ½ in.
3.________ Depth of water is greater than draft of vessel.
4.________ All empty tanks should be opened and checked for
   liquids. All tanks containing liquids should be sounded for
   liquid levels. All tank levels should be recorded.
5.——— Weight certificates obtained or the weights used
   for the inclining actually weighed using certified scales.
6.——— Initial angle of heel is less than 0.5° and the trim
   difference from design is less than 1 % of the LBP. If more trim
   is allowed, as-trimmed hydrostatics must be used in calcula-
   tions.

Note: X1.1—In some cases, if trim is different from design, as-trimmed
hydrostatics must always be used (that is, Navy inclines).

X1.2 Freeboard/Draft Readings:

1.—— At least five freeboard readings on each side at
   approximately the same intervals along the length at readily
   identifiable locations (for example, ends of deck houses). A
   verified draft mark reading may be substituted for a freeboard
   reading.
   (a) Each data point is to consist of:
      1. Freeboard reading (f) taken from the top of the
         bulwark to the point where the plumb bob touches the water.
      2. Bulwark height (b) reading at each location.
      3. Deck plating thickness (t) from the structural plan.
      4. Molded depth (D) at each location from the lines
         plan.
   (b) Molded draft = molded depth plus bulwark height plus
      deck plating thickness minus freeboard reading
      \[ d = D + b + t - f \].
2.——— Draft mark readings:
   (a) Taken from a small boat.
   (b) Port and starboard; forward, midship, and aft.
   (c) Longitudinal locations from a known reference point.
3.——— Plot of waterline (draft versus distance from
   forward perpendicular).
   (a) Note that draft readings are extreme (bottom of keel)
   while drafts from freeboard readings are molded (top of keel).
4.——— Specific gravity of water (hydrometer reading) and
   water temperature readings.

X1.3 Weight Movements:

1.——— Pendulums:
   (a) At least three; can be located on different decks and do
   not have to be on centerline.
   (b) Length of pendulums is measured from the pivot point
   to the top of the batten.
   (c) Pendulums should be of different lengths; to get re-
   quired angle of deflection, pendulums need to be at least 10 ft
   long. The longer the better if sheltered from the wind.
   Pendulum unrestricted through maximum angle expected.
   (d) Thick oil in bucket to dampen movement of pendulums.
      Pendulums with dampers are recommended.
      (e) Pendulum support is fixed so it cannot be accidently
      moved during the inclining.
   2.——— Battens:
      (a) Pencil marks placed on battens to record the position
      of the pendulum wires.
      (b) Batten is fixed so it can not be accidently moved
      during the inclining.
      (c) Battens should never be reset once inclining begins and
      movements are being recorded.
3.——— Weights:
   (a) Record initial position (vertical, transverse, longitudinal
   distances from known reference points such as distance above
   the deck, distance from the end of a deckhouse and distance
   from the centerline).
4.——— Weight Movements:
   (a) At least three to each side of the reference position.
   (b) Deflection of the pendulums at maximum moment
   should be at least 6 in. to each side of the initial position.
   (c) Maximum angle of heel should not be greater than 4°;
   value of tangent must be less than 0.069 93. Typical angle of
   heel should be between 2 and 3°.
   (d) Moment equals weight times distance moved; calcu-
   lated and summed for all weights moved for each movement.
   (e) Tangent equals pendulum deflection divided by pendu-
   lum length. When calculating the tangent, the deflection and
   the length must be in the same units (that is, inches or feet).
   (f) During each movement, ensure that:
      1. There are no taut mooring lines other than those
         attached to temporary pads on centerline;
      2. Pendulum weight is not touching side of bucket; and
      3. Pendulum is not touching batten.
   (g) Plot of moment-tangent curve:
      1. Plot each tangent value calculated for each weight
         movement. The average of the three pendulum readings may
         be graphed instead of plotting each of the readings only if the
tan \( \theta \) values measured among the pendulums are consistent.

2. Plot must be a straight line but it doesn’t have to pass through the origin.

3. Curved line means unaccounted for free surface, gusting winds or the vessel is touching the bottom and should not be accepted.

X1.4 Post-Inclining:
1.________ Check drafts/freeboards to ensure consistency with first measurements.
   (a) Note that draft readings are extreme (bottom of keel) while drafts from freeboard readings are molded (top of keel).
2.________ Survey tanks if drafts have changed.

X1.5 Survey of Items to Be Added, Removed, or Relocated:
1.________ Record weight, vertical center of gravity, longitudinal center of gravity, and transverse center of gravity (if required) for each item. Weights become more critical as the size of the vessel becomes smaller.
2.________ Typical weights to add:
   (a) Liferafts/lifesaving equipment;
   (b) Seating;
   (c) Liquids in engines and other machinery;
   (d) Paneling;
   (e) CO\(_2\) bottles/firefighting equipment;
   (f) Fenders;
   (g) Deck coverings/tiles and underlaminets;
   (h) Cables for winches;
   (i) Lines and hawser;
   (j) Engineersroom insulation;
   (k) Ventilation ducts;
   (l) Galley equipment (stoves and refrigerators);
   (m) Mattresses;
   (n) Paint (on surfaces to be painted);
   (o) Dampers;
   (p) Electronic equipment in the pilothouse; and
   (q) Masts and navigation lights.
3.________ Typical weights to deduct:
   (a) Inclining weights and pendulum setup;
   (b) Personnel on board;
   (c) Liquids on board (in tanks and bilges but excluding liquids in engines and other machinery);
   (d) Workers equipment;
   (e) Scrap metal;
   (f) Scaffolding; and
   (g) Dunnage.
4.________ Typical weights to relocate:
   (a) Paneling;
   (b) Lifesaving equipment;
   (c) Fenders and mooring equipment; and
   (d) Fire-extinguishing equipment.

X2. SAMPLE DATA SHEETS

X2.1 Figs. X2.1-X2.7 are sample data sheets.

<table>
<thead>
<tr>
<th>Stability Test Rough Data</th>
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**Description of Vessel:**

Name __________________________________________________________

Type __________________________________________________________

Builder _______________________________________________________

Hull Number ___________________________________________________

Vessel inclined at _____________________________________________

Date __________________ Time __________________

Test conducted by _____________________________________________

Test witnessed by _____________________________________________

Description of weather conditions _______________________________

Specific gravity of water _______________________________________

Temperature of water __________________________________________

Weights certified by: Weigh master (certificate attached) □

Reviewing authority □

FIG. X2.1 Stability Test Rough Data
### Items to Be Added

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<th>Longitudinal Center</th>
<th>Transverse Center (if needed)</th>
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**Tanks:**

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**FIG. X2.2 Items To Be Added**
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**TANKS:**

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FIG. X2.3 Items To Be Removed
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FIG. X2.4 Items To Be Relocated
Freeboard Readings

$f =$ measured freeboard,
$t =$ deck thickness,
$D =$ molded depth from lines drawing,
$b =$ measured bulwark height, and
$d =$ calculated molded draft.

Without Bulwark or Side Shell Coaming
\[ d = D + t - f \]

Or

With Bulwark or Side Shell Coaming
\[ d = D + t + b - f \]

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<tr>
<th>Location</th>
<th>$f$</th>
<th>$t$</th>
<th>$D$</th>
<th>$b$</th>
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Draft Mark Readings

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FIG. X2.5 Freeboard Readings
### FIG. X2.6 Condition 0—Preliminary Report

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<th>Length to Batten</th>
<th>Weight</th>
<th>Distance from Initial Positions</th>
<th>Total Inclining Moment</th>
<th>Pendulum Deflections</th>
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#### Inclining Weights

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**FIG. X2.7 Stability Test Graph—Preliminary Results**
X3. STABILITY TEST DATA

X3.1 Figs. X3.1-X3.10 are stability test data.

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<td>Vessel Inclined At</td>
</tr>
<tr>
<td>Date Built</td>
<td>Date</td>
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<tr>
<th>Machinery</th>
<th>Plans Furnished By</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Offsets Measured By</td>
</tr>
<tr>
<td>Classed By</td>
<td>Curves of Form Computed By</td>
</tr>
<tr>
<td>Inspected: □</td>
<td>Test Conducted By</td>
</tr>
<tr>
<td>Safety Certificate: □</td>
<td>Stability Calculations Made By</td>
</tr>
<tr>
<td>Load Line □</td>
<td>Sister Vessels</td>
</tr>
</tbody>
</table>

**FIG. X3.1 Stability Test Data**

### Stability Test

**Principal Dimensions**

<table>
<thead>
<tr>
<th>Length over all</th>
<th>ft</th>
<th>in (     ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length between perpendiculars which are at the extremities of</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Length between draft marks, condition</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Breadth, extreme, at feet above base</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Breadth, molded, amidships at feet above base</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Breadth at load water line</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Depth amidships, from molded base to bottom of keel</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Apparent full-load mean draft for stability</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Displacement, sea water, tons (2240 lb), at above full-load draft</td>
<td>tons</td>
<td></td>
</tr>
<tr>
<td>Freeboard amidships at above full-load draft</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Freeboard at low point of sheer (feet aft of amidships)</td>
<td>ft</td>
<td>in (     ft)</td>
</tr>
<tr>
<td>Location of ports, in hull, which may affect stability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**General Information**

<table>
<thead>
<tr>
<th>Names and duties of official observers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designers represented by</td>
</tr>
<tr>
<td>Builders represented by</td>
</tr>
<tr>
<td>Owners represented by</td>
</tr>
<tr>
<td>Weather, tide, and mooring conditions</td>
</tr>
<tr>
<td>Condition of ship as to completeness and as to water in boilers, machinery, and bilges</td>
</tr>
</tbody>
</table>

**FIG. X3.2 Stability Test—Principal Dimensions**
<table>
<thead>
<tr>
<th>Sketch Showing Hog, Sag, Trim, Drag, and Location of Draft Marks, Freeboards, and Perpendiculars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft from draft marks when inclined</td>
</tr>
<tr>
<td>Forward</td>
</tr>
<tr>
<td>Aft</td>
</tr>
<tr>
<td>Amidships</td>
</tr>
<tr>
<td>Port</td>
</tr>
<tr>
<td>Starboard</td>
</tr>
<tr>
<td>Distance between &quot;curves of form&quot; perpendiculars</td>
</tr>
<tr>
<td>Bottom of keel below base line</td>
</tr>
<tr>
<td>Molded</td>
</tr>
<tr>
<td>Keel</td>
</tr>
<tr>
<td>keel</td>
</tr>
<tr>
<td>Molded</td>
</tr>
<tr>
<td>Keel</td>
</tr>
<tr>
<td>Forward</td>
</tr>
<tr>
<td>Aft</td>
</tr>
<tr>
<td>Mean of amidships P and S</td>
</tr>
<tr>
<td>Total displacement at above draft F.W., S. W.</td>
</tr>
<tr>
<td>Specific gravity of water</td>
</tr>
<tr>
<td>Total displacement corrected for density</td>
</tr>
</tbody>
</table>

FIG. X3.3 Stability Test Sketch—Condition 0
<table>
<thead>
<tr>
<th>No. Location</th>
<th>Length to Batten</th>
<th>Weight</th>
<th>Distance from Initial Positions</th>
<th>Total Inclining Moment</th>
<th>Pendulum Deflections</th>
<th>Tangents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
<td>No.</td>
<td>Port Starboard</td>
<td>ft-ft-ft-ton-ft-ton</td>
<td>in. in.</td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>1st Trial</td>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3d</td>
<td></td>
</tr>
<tr>
<td>2d</td>
<td>2d Trial</td>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3d</td>
<td></td>
</tr>
<tr>
<td>3d</td>
<td>3d Trial</td>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3d</td>
<td></td>
</tr>
<tr>
<td>Inclining Weights</td>
<td>4th Trial</td>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>5th Trial</td>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3d</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>Initial Position</td>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td></td>
</tr>
<tr>
<td>No. Port</td>
<td>Starboard 6th Trial</td>
<td></td>
<td></td>
<td></td>
<td>2d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3d</td>
<td></td>
</tr>
</tbody>
</table>

FIG. X3.4 Condition 0—Final Report

STABILITY TEST

FIG. X3.5 Stability Test Graph—Final Results
Stability Test

Ship at Time of Stability Test—Condition 0

<table>
<thead>
<tr>
<th>From Hydrostatic Curves</th>
<th>From Independent Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>tons</td>
<td>tons</td>
</tr>
<tr>
<td>ft</td>
<td>ft</td>
</tr>
<tr>
<td>ft</td>
<td>ft</td>
</tr>
<tr>
<td>ft</td>
<td>ft</td>
</tr>
<tr>
<td>ft</td>
<td>ft</td>
</tr>
<tr>
<td>ft</td>
<td>ft (from figure)</td>
</tr>
<tr>
<td>ft</td>
<td>ft (from figure)</td>
</tr>
</tbody>
</table>

Corrected displacement
Mean virtual metacentric height obtained from plot of inclining moment
moments versus tangents of angles of heel—
displacement × tangent
Correction for free surface
Mean metacentric height = G. M. =
Transverse metacenter above the base line corresponding to draft at L. C. F. (corrected for hog or sag)
Transverse metacenter above the base line corrected (for trim, and hog or sag)
C. G. above base line
Longitudinal metacenter above C. G.
Moment to alter trim 1 foot Long. GM × ∆
Trim by stern, bow
Trimming lever = Trim × moment to trim
L.C.B. forward, aft of amidships, which is ft forward, aft of frame No.
C. G. forward, aft of amidships
Period of complete roll
Apparent radius of gyration of vessel—k = \( \frac{T \sqrt{GM}}{1.108} \)
Rolling Constant—C = \( \frac{T \sqrt{GM}}{B} \)

\( ^{A} \) Water in bilges. The bilges should be entirely free of water; but should this be impossible, correction should be made in the derived GM. The details of this correction should form part of this report.

\( ^{B} \) If the trim is excessive, independent calculations should be made to obtain the positions of the center of buoyancy and transverse metacenter and the position of the center of gravity determined therefrom. These calculations should be incorporated in this booklet.

FIG. X.3.6 Stability Test Results at Condition 0 from Hydrostatic Curves and Independent Calculation

Stability Test

<table>
<thead>
<tr>
<th>Data for Tanks</th>
<th>C. G. Above base</th>
<th>C. G. Above from M. P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td>Weight, tons</td>
<td>Vertical Moments, ft-tons</td>
</tr>
<tr>
<td>Sounding</td>
<td>C. G. Above base</td>
<td>Feet Aft</td>
</tr>
<tr>
<td>Net Inertia of Free Surface</td>
<td>C. G. Above from M. P.</td>
<td>After Moments, ft-tons</td>
</tr>
<tr>
<td>Inertia, ft³-ton</td>
<td>Items</td>
<td>Feet Forward</td>
</tr>
<tr>
<td>Items</td>
<td>C. G. Above from M. P.</td>
<td>Forward Moments, ft-tons</td>
</tr>
</tbody>
</table>

FIG. X.3.7 Stability Test—Data for Tanks

25
## Stability Test

**Ship Light—Condition 1**

Ship complete in every respect, with water in boilers at steaming level and liquids in machinery and piping, but with all tanks and bunkers empty and no passengers, crew, cargo, stores, or baggage on board.

<table>
<thead>
<tr>
<th>List of Major Equipment, etc., included in Condition 1 as Shown</th>
<th>Items</th>
<th>Displacement and Weight</th>
<th>C. G. Above Base</th>
<th>C. G. Above from M. P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballast, boats, rafts, cargo booms, anchors, guns, armor, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items</th>
<th>Weight, tons</th>
<th>C.G. Above Base, ft</th>
<th>C.G. from M.P., Feet</th>
<th>Ship in Condition 0</th>
<th>Weight to Complete</th>
<th>Weight to Relocate</th>
<th>Weight to Remove</th>
<th>C.G. Above from M.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Ballast</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Molded Keel—Draft at longitudinal center of flotation corresponding to above displacement for _______ water _______ ft

Transverse metacenter above base at L.C.F. draft, uncorrected for trim _______ ft

C.G. above base _______ ft

Metacentric height, uncorrected for trim, G.M. _______ ft

Metacentric height, corrected for G.M. _______ ft

<table>
<thead>
<tr>
<th>Longitudinal metacenter above C.G. at L.C.F. draft</th>
<th>_______ ft</th>
<th>L.C.F. aft, forward of amidships</th>
<th>_______ ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment to alter trim 1 foot at L.C.F. draft, L long GM x 1/2</td>
<td>_______ ft-tons</td>
<td>Difference between L.C.F. and amidships draft</td>
<td>_______ ft</td>
</tr>
<tr>
<td>C.B. of ship on even keel at L.C.F. draft, aft, forward 1 ft</td>
<td>_______ ft</td>
<td>Molded draft amidships</td>
<td>_______ ft</td>
</tr>
<tr>
<td>C.G. aft, forward of amidships</td>
<td>_______ ft</td>
<td>Draft on draft marks, forward</td>
<td>_______ ft</td>
</tr>
<tr>
<td>Trimming lever</td>
<td>_______ ft</td>
<td>Draft on draft marks, aft</td>
<td>_______ ft</td>
</tr>
</tbody>
</table>

**FIG. X3.8 Ship Light—Condition 1**
FIG. X3.9 Stability Test—Condition Description

<table>
<thead>
<tr>
<th>Description of Condition</th>
<th>Items</th>
<th>Displacement and Weight</th>
<th>C. G. Above Base</th>
<th>C. G. Above from M. P.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>tons</td>
<td>Lever</td>
<td>Vertical Moments, ft-tons</td>
</tr>
<tr>
<td>Ship in Condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molded Keel—Draft at longitudinal center of flotation corresponding to above displacement for water ______ ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse metacenter above base at L.C.F. draft, uncorrected for trim ______ ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.G. above base ______ ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metacentric height, uncorrected for free surface</td>
<td></td>
<td></td>
<td>[corrected for trim uncorrected for trim] G.M.</td>
<td></td>
</tr>
<tr>
<td>Correction for free surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metacentric height, corrected for free surface</td>
<td></td>
<td></td>
<td>[corrected for trim uncorrected for trim] G.M.</td>
<td></td>
</tr>
<tr>
<td>Longitudinal metacenter above C.G. at L.C.F. draft ______ ft</td>
<td></td>
<td></td>
<td></td>
<td>Longitudinal center of floatation, aft, forward of amidships ______ ft</td>
</tr>
<tr>
<td>Moment to alter trim 1 foot at L.C.F. draft, ______ ft-tons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.B. of ship on even keel at L.C.F. draft, aft, forward of amidships ______ ft</td>
<td></td>
<td></td>
<td></td>
<td>Molded draft amidships ______ ft</td>
</tr>
<tr>
<td>C.G. aft, forward of amidships ______ ft</td>
<td></td>
<td></td>
<td></td>
<td>Draft on draft marks, forward ______ ft</td>
</tr>
<tr>
<td>Trimming lever ______ ft</td>
<td></td>
<td></td>
<td></td>
<td>Draft on draft marks, aft ______ ft</td>
</tr>
<tr>
<td>Trim, aft, forward ______ ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. X3.10 Stability Test—Conclusive Remarks

**NOTE**—This sheet should be used for any explanations that may be required other than those covered by the notes on the previous sheets. In case the results of the stability test show that under certain conditions caution in loading and handling the vessel is necessary, particularly in regard to the effect of deck loads or free surface, a detailed statement to this effect should be made here.

FIG. X3.10 Stability Test—Conclusive Remarks
Standard Guide for Selection of Shipboard Incinerators

This standard is issued under the fixed designation F 1322; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
   1.1 This guide covers selection criteria to assist procurers in selecting the appropriate incinerator for their needs.
   1.2 This guide is a companion document to Specification F 1323.
   1.3 This guide does not apply to incinerator systems on special incinerator ships, for example, for burning industrial wastes such as chemicals, manufacturing residues, and so forth.

2. Referenced Documents
   2.1 ASTM Standards:
       2.1.1 F 1323 Specification for Shipboard Incinerators
   2.2 Other Document:
       2.2.1 MARPOL 73/78

3. Selecting the Incinerator Size and Installed Location
   3.1 A number of factors will govern the selection of the size and type of shipboard incinerator and full consideration must be given to each. The installed operating location of the unit is of equal importance to ensure low-cost operating, ease of charging, ease of cleaning, and so forth. Consideration should be given to the following:
      3.1.1 Maximum amount of each type of waste that will be incinerated each day.
      3.1.2 The normal number of hours per day that the incinerator will be in operation: loading procedure batch/continuous over operating hours.
      3.1.3 Can wet and dry material be loaded into the incinerator so that a large volume of auxiliary fuel is not required?
      3.1.4 Can the incinerator be installed on the ship in a location near the major source of refuse so as to minimize the manpower requirements during loading operations?
      3.1.5 Will ashes be able to be removed easily if the incinerator is installed in the machinery space or on a lower deck? Will ash removal be manual (shoveling) or semiautomatic (plow)?

4. Estimating Daily Quantities of Waste to Be Incinerated
   4.1 Size of Ship’s Crew:
      4.1.1 Galley waste estimate: 2 lb per crew member per day.
      4.1.2 Crews quarters waste estimate: 1.5 lb per room per day.
   4.2 Number of Passengers Carried:
      4.2.1 Galley waste estimate: 3⁄4 lb per meal served.
      4.2.2 Passenger quarters waste estimate: 1.5 lb per room per day.
   4.3 Stores—Including amount of packages and packages that would add to the ship’s garbage.
   4.4 Spent oil.

5. Factors for Selection
   5.1 Type of Unit—Two-stage controlled air, or single-stage, compact high-temperature cyclone incinerator.
   5.2 Size of unit (number of people on board).
   5.3 Loading considerations (manual loader) (batch or continuous).
   5.4 Auxiliary liquid waste capability (sludge oil/waste oil).
   5.5 Installation considerations (indoor/outdoor).
   5.6 Environmental considerations (in port usage).
   5.7 Heat recover options (amount of steam or hot water).
   5.8 Ash removal.
   5.9 Induced draft fan requirements.
   5.10 Modular/package.
   5.11 Dimensions/weight.

6. Classification of Shipboard Wastes and Incinerators
   6.1 The basis for satisfactory incinerator operation is the proper analysis of the waste to be destroyed and the selection of proper equipment to best destroy that particular waste.
6.2 As a guide, mixtures of waste most commonly encountered have been classified into types of waste, together with the British Thermal Unit (Btu) values and moisture contents of the mixtures. A concentration of one specific waste in the mixture may change the Btu value or the moisture content, or both, of the mixture. A concentration of more than 10% by weight of catalogs, magazines, or packaged paper will change the density of the mixture and affect burning rates.

6.3 Similarly, incinerators have been classified by their capacities and by the types of wastes they are capable of incinerating.

6.4 Classification of Shipboard Wastes—The following classification of shipboard wastes differs from the definition of garbage as found in Annex V of MARPOL 73/78, which includes all of the types listed on this page.

6.4.1 Type 0—Trash, a mixture of highly combustible waste, such as paper, cardboard, cartons, wood boxes, and combustible floor sweepings from commercial and industrial activities. The mixtures contain up to 10% by weight of plastic bags, coated paper, laminated paper, treated corrugated cardboard, oil rags, and plastic or rubber scraps.

6.4.1.1 This type of waste contains 10% moisture, 5% incombustible solids, and has a heating value of 8500 Btu/lb as fired.

6.4.2 Type 1—Rubbish, a mixture of combustible waste, such as paper, cardboard cartons, wood scrap, foliage, and combustible floor sweepings, from domestic, commercial, and industrial activities. The mixture contains up to 20% moisture, 10% incombustible solids, and has a heating value of 6500 Btu/lb as fired.

6.4.2.1 This type of waste contains 25% moisture, 10% incombustible solids, and has a heating value of 4300 Btu/lb as fired.

6.4.3 Type 2—Refuse, consisting of an approximately even mixture of rubbish and garbage by weight.

6.4.3.1 This type waste is common to passenger ships occupancy, consisting of up to 50% moisture, 7% incombustible solids, and has a heating value of 4300 Btu/lb as fired.

6.4.4 Type 3—Garbage, consisting of animal and vegetable wastes from restaurants, cafeterias, galleys, sick bays, and like installations.

6.4.4.1 This type of waste contains up to 70% moisture, up to 5% incombustible solids, and has a heating value of 2500 Btu/lb as fired.

6.4.5 Type 4—Aquatic life forms and animal remains, consisting of carcasses, organs and solid organic wastes from vessels carrying animal type cargos, consisting of up to 85% moisture, 5% incombustible solids, and having a heating value range of 1000 Btu/lb as fired.

6.4.6 Type 5—By-product waste, liquid or semiliquid, such as tar, paints, solvents, sludge, oil, waste oil, and so forth, from shipboard operations. Btu values must be determined by the individual materials to be destroyed.

6.4.7 Type 6—Solid by-product waste, such as rubber, plastics, wood waste, and so forth, from industrial operations. Btu values must be determined by the individual materials to be destroyed.

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4 The original source of data for these classifications is the Incinerator Institute of America Waste Classification, available from the Incinerator Institute of America, 60 E. 42nd St., New York, NY 10017.
Standard Specification for Shipboard Incinerators

This standard is issued under the fixed designation F 1323; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, manufacture, performance, operation, functioning, and testing of incinerators intended to incinerate garbage and other shipboard wastes generated during the ship’s normal service (that is, maintenance, operational, domestic, and cargo-associated wastes).

1.2 This specification is a companion document to Guide F 1322.

1.3 This specification applies to those incinerator plants with capacities up to 1500 kW per unit.

1.4 Additional information is given in Appendix X1-Appendix X9.

1.5 This specification does not apply to systems on special incinerator ships, for example, for burning industrial wastes such as chemicals, manufacturing residues, and so forth.

1.6 This specification does not address the electrical supply to the unit nor the foundation connections and stack connections.

1.7 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. If an incinerator is to be operated in littoral regions, the strictest governing regulations for those countries in which the incinerator may operate would form the requirement basis. See 5.11.

2. Referenced Documents

2.1 ASTM Standards:
   F 1166 Practice for Human Engineering Design for Marine Systems, Equipment and Facilities
   F 1322 Guide for Selection of Shipboard Incinerators
   B31.1 Power Piping
   ANSI/NFPA No. 70 National Electrical Code
   NEC Article 430-7
   ASME Boiler and Pressure Vessel Code:
   Section IX, Welding and Brazing Qualifications
   SOLAS 74 International Convention for the Safety of Life at Sea
   Underwriter’s Laboratory Standards:
   UL 506 Standard for Specialty Transformers
   UL 814 Standard for Gas-Tube Signs and Ignition Cables
   Other Documents:
   International Convention for the Preventing of Pollution from Ships (1973), as modified by the Protocols of 1978 (73/78) and 1997 and associated Annexes

3. Terminology

3.1 Definitions:

3.1.1 cargo-associated waste—all materials that have become waste as a result of use on board a ship for cargo stowage and handling. Cargo-associated waste includes but is not limited to dunnage, shoring pallets, lining and packing materials, plywood, paper, cardboard, wire, and steel strapping.

3.1.2 cargo residues—for the purposes of this specification, the remnants of any cargo material on board that cannot be placed in proper cargo holds (loading excess and spillage) or which remain in cargo holds and elsewhere after unloading procedures are completed (unloading residual and spillage). However, cargo residues are expected to be in small quantities.

3.1.3 domestic waste—all types of food waste, sewage, and waste generated in the living spaces on board the ship.

3.1.4 fishing gear—any physical device or part thereof or combination of items that may be placed on or in the water.
with the intended purpose of capturing, or controlling for subsequent capture, living marine or freshwater organisms.

3.1.5 food wastes—any spoiled or unspoiled victual substances, such as fruits, vegetables, dairy products, poultry, meat products, food scraps, food particles, and all other materials contaminated by such waste, generated aboard ship, principally in the galley and dining areas.

3.1.6 garbage—all kinds of victual, domestic, and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically. Those substances which are defined or listed in Annexes, other than Annex V, to the International Convention for the Preventing of Pollution From Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78) are excluded.

3.1.7 graywater—drainage from galleys, pantries, showers, laundries, baths, and handbasins as long as it is not mixed with sewage.

3.1.8 incinerator—shipboard facilities for incinerating solid wastes approximating in composition to household waste and liquid wastes arising from the operation of the ship, for example, domestic waste, cargo-associated waste, maintenance waste, operational waste, cargo residues, fishing gear, and so forth. These facilities may be designed to use or not to use the heat energy produced.

3.1.9 maintenance waste—materials collected by the engine department and the deck department while maintaining and operating the ship, such as soot, machinery deposits, scraped paint, deck sweeping, wiping wastes, oily rags, and so forth.

3.1.10 oily rags—rags that have been saturated with oil as controlled in Annex I to the Convention. Contaminated rags are rags that have been saturated with a substance defined as a harmful substance in the other Annexes to the Convention.

3.1.11 operational wastes—all cargo-associated wastes and maintenance waste (including ash and clinkers) and cargo residues defined as garbage in 3.1.6.

3.1.12 plastic—a solid material that contains as an essential ingredient one or more synthetic organic high polymers and is formed (shaped) during either manufacture of the polymer or the fabrication into a finished product by heat or pressure, or both. Plastics have material properties ranging from hard and brittle to soft and elastic. Plastics are used for a variety of marine purposes including, but not limited to, packaging (vapor-proof barriers, bottles, containers, liners), ship construction (fiberglass and laminated structures, siding, piping, insulation, flooring, carpets, fabrics, paints and finishes, adhesives, electrical and electronic components), disposable eating utensils and cups, bags, sheeting, floats, fishing nets, strapping bands, rope, and line.

3.1.13 sewage—human body waste and the waste from toilets and other receptacles intended to receive or retain body wastes. Sewage is drainage and other waste from toilets, urinals, and water closet scuppers as well as drainage from medical premises and from spaces containing living animals.

3.1.14 ship—a vessel of any type operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft, and fixed or floating platforms.

3.1.15 sludge oil—residues from fuel and lubricating oil separators, waste lubricating oil from main and auxiliary machinery, waste oil from bilge water separators, drip trays, and so forth.

3.1.16 waste—useless, unneeded, or superfluous matter which is to be discarded.

4. Ordering Information

4.1 Orders shall include the following information, in accordance with Guide F 1322:

4.1.1 Sizing requirements.
4.1.2 Processing rate requirements.
4.1.3 Additional control requirements.
4.1.4 Any additional requirements required by the purchaser to meet special needs.

5. Materials and Manufacture

5.1 Metal parts of the incinerator exposed to the combustion process shall be made of materials listed in Section I of the ASME Boiler and Pressure Vessel Code.

5.2 Where welded construction is used, welded joint design details, welding, and nondestructive testing of the combustion chamber shall be in accordance with Section I of the ASME Code. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.

5.3 Piping and piping components associated with incinerators for fuel, sludge, and liquid cargo residues shall comply with ANSI B31.1 for design and material requirements. Fuel oil pressure piping between service pumps and burners shall have a relief valve fitted which will discharge into the suction line or back into the tank. Pressure piping shall be of seamless steel with a thickness of at least Schedule 80. Short lengths of steel, or annealed copper nickel, nickel copper, or copper pipe and tubing may be used at the burners. The use of nonmetallic materials for fuel lines is prohibited. Valves and fittings may be threaded in sizes up to and including 2-in. normal pipe size (NPS) (60-mm outside diameter), but threaded unions are not to be used on pressure lines in sizes 1-in. NPS (33-mm outside diameter) and over.

5.4 If equipped with an electrically, hydraulically, or pneumatically activated valve, the valve shall be designed to fail closed or in the safe position on loss of power whichever is more appropriate to the applicable system.

5.5 All rotating or moving mechanical and exposed electrical parts shall be protected against accidental contact. All electrical devices shall be enclosed in drip-proof or watertight enclosures.

5.6 The coatings or paints shall not contain any heavy metals, such as, chromium, lead, tin, and so forth, or other materials banned by federal, state, or local authorities.

5.7 Asbestos, mercury, cadmium, polychlorinated biphenyls (PCBs), and chlorinated plastics shall not be used in the construction of the incinerator or any subsystem, including gaskets or lagging materials.

5.8 Refractory shall be resistant to thermal shocks and resistant to normal ship’s vibration. The refractory design temperature shall be equal to the combustion chamber design temperature plus 20% (see 6.1).
5.9 Incinerating systems shall be designed such that corrosion will be minimized on the inside of the systems.

5.10 In systems equipped for incinerating liquid wastes, safe ignition and maintenance of combustion shall be ensured, for example, by a supplementary burner using gas oil/diesel oil or equivalent.

5.11 The incinerating furnace may be charged with solid waste either by hand or automatically. In every case, fire dangers must be avoided and charging must be possible without danger to the operating personnel.

5.11.1 For instance, where charging is carried out by hand, a charging lock may be provided which ensures that the charging space is isolated from the fire box as long as the filling hatch is open.

5.11.2 Where charging is not affected through a charging lock, an interlock shall be installed to prevent the charging door from opening while the incinerator is in operation or while the furnace temperature is above 220°C (428°F).

5.12 Incinerators equipped with a feeding sluice shall ensure that the material charged will move from the sluice to the combustion chamber. Examples for accomplishing this are the use of a clear path down or a mechanical pusher.

5.13 Interlocks shall be installed to prevent ash removal doors from opening while burning is in progress or while the furnace temperature is above 220°C (428°F).

5.14 The incinerator shall be provided with a safe observation port of the combustion chamber to provide visual control of the burning process and waste accumulation in the combustion chamber. Neither heat, flame, nor particles shall be able to pass through the observation port. An example of a safe observation port is high-temperature glass with a metal closure.

5.15 The outside surface of the combustion chamber(s) shall be shielded from contact such that people would not be exposed to extreme heat (maximum 20°C (68°F) above ambient temperature) or direct contact of surface temperatures exceeding 60°C (140°F). Examples for alternatives to accomplish this are a double jacket with airflow in between or an expanded metal jacket.

5.16 Safety interlocks shall be provided to ensure that the incinerator cannot be operated if the shock cooling subsystem is not functioning properly.

5.17 Electrical Requirements:

5.17.1 General—Installation requirements shall apply to controls, safety devices, and burners on incinerators.

5.17.1.1 A disconnecting means capable of being locked in the open position shall be installed at an accessible location at the incinerator so that the incinerator can be disconnected from all sources of electrical potential. This disconnecting means shall be an integral part of the incinerator or adjacent to it (see 7.1).

5.17.1.2 All rotating or moving parts that may cause injury shall be guarded to avoid accidental contact.

5.17.1.3 The electrical equipment shall be so arranged so that failure of this equipment will cause the fuel supply to be shut off.

5.17.1.4 The power supply to the electrical control system shall be from a two-wire branch circuit that has a grounded conductor; otherwise, an isolation transformer with a two-wire secondary shall be provided. When an isolation transformer is provided, one side of the secondary winding shall be grounded.

5.17.1.5 One side of all coils shall be electrically located in the grounded side of the circuit. All switches, contacts, and overcurrent devices shall be electrically located in the ungrounded or “hot” side of the circuit. All electrical contacts of every safety device installed in the same control circuit shall be electrically connected in series. However, special consideration shall be given to arrangements when certain devices are wired in parallel.

5.17.1.6 All electrical components and devices shall have a voltage rating commensurate with the supply voltage of the control system.

5.17.1.7 All electrical devices shall be at least NEMA Type 2 (Drip tight). Electric equipment exposed to the weather shall be at least NEMA Type 4.

5.17.1.8 All electrical and mechanical control devices shall be of a type tested and accepted by a nationally recognized testing agency.

5.17.1.9 The design of the control circuits shall be such that, limit, and primary safety controls shall directly open a circuit that functions to interrupt the supply of fuel to combustion units.

5.17.2 Overcurrent Protection:

5.17.2.1 Conductors for interconnecting wiring that is smaller than the supply conductors shall be provided with overcurrent protection based on the size of the smallest interconnecting conductors external to any control box.

5.17.2.2 Overcurrent protection for interconnecting wiring shall be located at the point where the smaller conductors connect to the larger conductors. However, overall overcurrent protection is acceptable if it is sized on the basis of the smallest conductors of the interconnecting wiring.

5.17.2.3 Overcurrent protection devices shall be accessible and their function shall be identified.

5.17.3 Motors:

5.17.3.1 Motors exposed to dripping or spraying oil or water shall be of drip-proof construction. All motors shall be fully guarded as installed.

5.17.3.2 Motors shall be provided with a corrosion-resistant nameplate specifying information in accordance with NEC, Article 430-7.

5.17.3.3 Motors shall be provided with running protection by means of integral thermal protection, or by overcurrent devices, or a combination thereof, in accordance with the manufacturer’s instructions that shall be based on the requirements of National Electrical Code, ANSI/NFPA No. 70.

5.17.3.4 Motors shall be rated for continuous duty and shall be designed for an ambient temperature of 50°C (122°F) or higher.

5.17.3.5 All motors shall be provided with terminal leads or terminal screws in terminal boxes integral with, or secured to, the motor frames.

5.17.4 Ignition System:

5.17.4.1 When automatic electric ignition is provided, it shall be accomplished by means of either a high-voltage electric spark, a high-energy electric spark, or a glow coil.
5.17.4.2 Ignition transformers shall conform to requirements of the UL Standard 506.

5.17.4.3 Ignition cable shall conform to requirements of the UL Standard 814.

5.17.5 Wiring:

5.17.5.1 All wiring for incinerators shall be rated for the maximum operating temperature to which it may be exposed. Such wiring shall be in accordance with ANSI/NFPA No. 70. All wiring between components shall have copper conductors and be constructed in accordance with the ANSI/NFPA No. 70.

5.17.5.2 All electrical wiring shall have a voltage rating commensurate with the voltage of the power supply.

5.17.5.3 Conductors shall be protected from physical damage where appropriate.

5.17.5.4 Conductors shall be sized on the basis of the rated current of the load they supply.

5.17.6 Bonding and Grounding:

5.17.6.1 Means shall be provided for grounding the major metallic frame or assembly of the incinerators.

5.17.6.2 Noncurrent carrying enclosures, frames, and similar parts of all electrical components and devices shall be bonded to the main frame or assembly of the boiler. Electrical components that are bonded by their installation do not require a separate bonding conductor.

5.17.6.3 When an insulated conductor is used to bond electrical components and devices, it shall show a continuous green color, with or without a yellow stripe.

6. Operating Requirements

6.1 The incinerator system shall be designed and constructed for operation with the following conditions:

- Maximum combustion chamber temperature: 1200°C (2150°F)
- Minimum combustion chamber temperature: 850°C (1560°F)
- Preheat temperature of combustion chamber: 650°C (1200°F)

For batch-loaded incinerators, there are no preheating requirements. However, the incinerator shall be so designed that the temperature in the actual combustion space shall reach 600°C (1110°F) within 5 min after start.

Prepurge, before ignition: at least 4 air changes in the chamber(s) and stack, but not less than 15 s

Time between restarts: at least 4 air changes in the chamber(s) and stack, but not less than 15 s

Postpurge, after shutoff of fuel oil: not less than 15 s after the closing of the fuel oil valve

6.2 Incinerating systems are to be operated with underpressure (negative pressure) in the combustion chamber such that no gases or smoke can leak out to the surrounding areas.

6.3 The incinerator shall have warning plates attached in a prominent location on the unit, warning against unauthorized opening of doors to combustion chamber(s) during operation and against overloading the incinerator with waste.

6.4 The incinerator shall have instruction plate(s) attached in a prominent location on the unit that clearly addresses the following:

6.4.1 Cleaning ashes and slag from the combustion chamber(s) and cleaning of combustion air openings before starting the incinerator (where applicable).

6.4.2 Operating procedures and instructions. These shall include system diagrams (combustion/cooling air, fuel, electrical, and waste processing), and procedures for proper start-up, normal operation, normal shutdown, and emergency shutdown.

6.5 To avoid the buildup of dioxins, the flue gas should be shock cooled to a maximum 350°C (660°F) within 2.5 m from the combustion chamber flue gas outlet.

7. Operating Controls

7.1 The entire unit shall be disconnected from all sources of electricity by means of one disconnect switch located near the incinerator (see 5.17.1.1).

7.2 There shall be an emergency stop switch located outside the compartment that stops all power to the equipment. The emergency stop switch shall also be able to stop all power to the fuel pumps. If the incinerator is equipped with an induced draft fan, the fan shall be capable of being restarted independently of the other equipment on the incinerator.

7.3 The control equipment shall be so designed that any failure of the following equipment will prevent continued operations and cause the fuel supply to be cut off.

7.3.1 Safety Thermostat/Draft Failure:

7.3.1.1 A flue gas temperature controller, with a sensor placed in the flue gas duct, shall be provided that will shut down the burner if the flue gas temperature exceeds the temperature set by the manufacturer for the specific design.

7.3.1.2 A combustion temperature controller, with a sensor placed in the combustion chamber, shall be provided that will shut down the burner if the combustion chamber temperature exceeds the maximum temperature.

7.3.1.3 A negative pressure switch shall be provided to monitor the draft and the negative pressure in the combustion chamber. The purpose of this negative pressure switch is to ensure that there is sufficient draft in the incinerator during operations. The circuit to the program relay for the burner shall be opened and an alarm activated before the negative pressure rises to atmospheric pressure. This is applicable to incinerators fitted with induced draft fans.

7.3.2 Flame Failure/Fuel Oil Pressure:

7.3.2.1 The incinerator shall have a flame safeguard control consisting of a flame-sensing element and associated equipment for shutdown of the unit in the event of ignition failure and flame failure during the firing cycle. The flame safeguard control shall be so designed that the failure of any component will cause a safety shutdown and prevent automatic restarting.

7.3.2.2 The flame safeguard control shall be capable of closing the fuel valves in not more than 4 s after a flame failure.

7.3.2.3 The flame safeguard control shall provide a trial-for-ignition period of not more than 10 s during which fuel may be supplied to establish flame. If flame is not established within 10 s, the fuel supply to the burners shall be immediately shut off automatically. Where a light oil pilot is used, the flame safeguard control shall provide a trial-for-ignition period for the pilot of not more than 10 s. If flame is not established within 10 s, the fuel supply to the pilot shall be immediately shut off automatically.

7.3.2.4 Whenever the flame safeguard control has operated because of failure of ignition, flame failure, or failure of any...
component, manual reset of the flame safeguard control shall be required for restart.

7.3.2.5 Flame safeguard controls of the thermostatic type, such as stack switches and pyrostats operated by means of an open bimetallic helix, are prohibited.

7.3.2.6 If fuel oil pressure drops below that set by the manufacturer, a failure and lockout of the program relay shall result. This also applies to a sludge oil used as a fuel. (Applies where pressure is important for the combustion process or where a pump is not an integral part of the burner.)

7.3.3 Motor Overload—All motors shall be protected in all phases by a thermal overload relay or circuit breaker with thermal overload protection that must be reset manually (see 5.17.3.3).

7.4 If there is a loss of power to the incinerator control/alarm panel (not remote alarm panel), the system shall shut down.

7.5 Fuel Supply—Two fuel control solenoid valves shall be provided in series in the fuel supply line to each burner. On multiple burner units, a valve on the main fuel supply line and a valve at each burner will satisfy this requirement. The valves shall be connected electrically in parallel so that both operate simultaneously.

7.6 After shutdown of the oil burner, the exhaust fan or ejector must continue to run until the fire box has cooled sufficiently. This does not apply in the case of an emergency manual trip.

8. Other Requirements

8.1 Documentation—A complete instruction and maintenance manual with drawings, electric diagrams, spare parts list, and so forth shall be furnished with each incinerator.

8.2 Installation—All devices and components shall, as fitted in the ship, be designed to operate when the ship is upright and when inclined at any angle of list up to and including 15° either way under static conditions and 22.5° under dynamic conditions (rolling) either way and simultaneously inclined dynamically (pitching) 7.5° by bow or stern.

8.3 Incinerator:

8.3.1 Incinerators are to be fitted with a pilot burner or spark ignition with sufficient energy to ensure a safe ignition and combustion. The combustion is to take place at sufficient negative pressure in the combustion chamber(s) to ensure no gases or smoke leaking out to the surrounding areas (see 7.3.1.3).

8.3.2 A drip tray is to be fitted under each burner and under any pumps, strainers, and so forth that require occasional examination.

9. Test Methods

9.1 Prototype Test Methods—An operating test method for the prototype of each design shall be conducted, with a test report completed indicating results of all test methods. The test methods shall be conducted to ensure that all of the control components have been properly installed and that all parts of the incinerator, including controls and safety devices, are in satisfactory operating condition. Test methods shall include those described in 9.3.

9.2 Factory Test Methods—For each unit, if preassembled, an operating test method shall be conducted to ensure that all of the control components have been properly installed and that all parts of the incinerator, including controls and safety devices, are in satisfactory operating condition. The requirements for prepurge and time between restarts referred to in 6.1 shall be verified at the time of the installation test method.

9.3 Installation Test Methods—An operating test method after installation shall be conducted to ensure that all of the control components have been properly installed and that all parts of the incinerator, including controls and safety devices, are in satisfactory operating condition. The requirements for prepurge and time between restarts referred to in 6.1 shall be verified at the time of the installation test method.

9.3.1 Flame Safeguard—The operation of the flame safeguard system shall be verified by causing flame and ignition failures. Operation of the audible alarm and visible indicator shall be verified. The shutdown times shall be verified.

9.3.2 Limit Controls—Shutdown as a result of the operation of the limit controls shall be verified.

9.3.2.1 Oil Pressure Limit Control—The lowering of the fuel oil pressure below the value required for safe combustion shall initiate a safety shutdown.

9.3.2.2 Air Pressure Limit Control—Systems using compressed air-oil atomization shall be tested to verify that the air pressure is above the minimum required for proper atomization.

9.3.2.3 Other Interlocks—Other interlocks provided shall be tested for proper operation as specified by the unit manufacturer.

9.3.3 Combustion Controls—The combustion control shall be stable and operate smoothly.

9.3.4 Programming Controls—Programming controls shall be verified as controlling and cycling the unit in the intended manner. Proper pre-purge, ignition, post-purge, and modulation shall be verified. A stopwatch shall be used for verifying intervals of time.

9.3.5 Fuel Supply Controls—The satisfactory operation of the two fuel control solenoid valves for all conditions of operation and shutdown shall be verified.

9.3.6 Low-Voltage Test Method—A low-voltage test method shall be conducted on the incinerator unit to demonstrate satisfactorily that the fuel supply to the burners will be automatically shut off before an incinerator malfunction results from the reduced voltage.

9.3.7 Switches—All switches associated with the unit shall be tested to verify proper operation.
10. Inspection

10.1 The manufacturer shall afford the purchaser’s inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer’s operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

11. Certification

11.1 Manufacturer’s certification that an incinerator has been constructed in accordance with this specification shall be provided (by letter or certificate).

12. Product Marking

12.1 Each incinerator shall be permanently marked indicating the following:

12.1.1 Manufacturer’s name or trademark.

12.1.2 Style, type, model, or other manufacturer’s designation for the incinerator.

12.1.3 Capacity to be indicated by net designed heat release of the incinerator in heat units per timed period; for example, British thermal units per hour, megajoules per hour, or kilocalories per hour.

12.1.4 ASTM designation of this specification (F 1323).

12.1.5 IMO certification, if required.

12.1.6 Other applicable nonmandatory requirements.

13. Quality Assurance

13.1 Incinerators shall be designed, manufactured, and tested in a manner that ensures they meet the requirements of this specification.

13.2 The incinerator manufacturer shall maintain the production quality of the incinerators that are designed, tested, and marked in accordance with this specification. At no time shall an incinerator be sold with this specification designation that does not meet the requirements herein (see Certification).

14. Keywords

14.1 incinerators; shipboard wastes; ships

SUPPLEMENTARY REQUIREMENTS

S1. For U.S. Government Procurement Only

S1.1 Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

S2. Referenced Documents

MIL-STD-882 System Safety Program Requirements
MIL-STD-901C Grade B Shock Requirements for Shock Tests, Shipboard Machinery, Equipment, and Systems
SNAME T&R Bulletin No. 3-37 Design Guide for Shipboard Airborne Noise Control

S3. Design Considerations

S3.1 The services that are available for the incinerator are as follows:

S3.1.1 440-V, 60-Hz, three-phase electrical power.

S3.1.2 Seawater—at 690 to 1206 kPa (100 to 175 psig) (actual value will vary over time and depending on shipboard location).

S3.1.3 Fresh Water—414 kPa (60 psig) up to 3.8 LPM (10 GPM); 21°C (70°F).

S3.1.4 Ship Service Compressed Air—at 862 kPa (125 psig) (air supply to the space at a maximum temperature of 32°C (90°F) with a wet bulb temperature of 27°C (81°F).

S3.1.5 Aviation Turbine Fuel Oil—Marine diesel, JP-5, or NATO designation F-44.

S3.1.6 Compartment Ventilation—As required.

S4. Materials and Manufacture

S4.1 Refractory material shall have a life expectancy of at least three years (see also 5.8).

S5. Operational Requirements

S5.1 To avoid building up of dioxins, the flue gas shall be shock-cooled to a maximum of 200°C (390°F) within 2.5 m (8.2 ft) from the combustion chamber flue gas outlet. (Replaces 6.5).

S5.2 The shock cooling subsystem shall also neutralize acidic gases to a pH of not less than 5.0 and sufficiently reduce the relative humidity to ensure that condensation will not occur in the exhaust stack or at the stack exhaust point.

S5.3 Stack emissions shall be measured including, but not limited to, carbon monoxide, oxygen, and smoke opacity.

S5.4 The incinerator shall have an internal pressure no greater than 125 Pa (0.018 psi) below ambient pressure for all rates of operation.

S5.5 The system shall not exhibit a visible steam plume from the output stack at 0°C (32°F) ambient. The stack shall operate without the emission of visible sparks or fly ash particles from the exhaust gas outlet.

7 Available from the Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.
8 Available from the Society of Naval and Marine Engineers, 601 Pavonia Ave., Jersey City, NJ 07306.
S5.6 A method for evacuation of any smoke or combustible gases entering the charging lock while the trash is transferred into the combustion chamber shall be provided.

S5.7 The reliability and maintainability characteristics of the thermal destruction system shall be such to ensure that the crew of a ship can, with a high degree of confidence, consistently dispose of the waste stream as defined by purchaser. The system shall be designed for an operational life at least ten years.

S5.8 Routine cleaning and preventive maintenance shall not require more than 1 h per day. The design of all components shall be consistent with an at-sea working environment. The incinerator shall have an operational availability \(A_o\) of not less than 0.90 over a six-month operating profile.

S5.9 For organizational level corrective maintenance, the incinerator shall have a geometric mean time to repair (MTTR\(_g\)) of less than 4 h 95% of the time and a maximum repair time (\(M_{\text{max}}\)) of less than 12 h 95% of the time. Repair times do not include the time required to cool down or heat up the incinerator. Organizational maintenance shall include any maintenance required during ship deployments, which are up to six months in duration. Organizational maintenance shall not require skills beyond that which is expected of an enlisted sailor with a twelfth-grade level of education. All other maintenance required to maintain the incinerator functioning for the six-year life expectancy shall be performed by an intermediate level maintenance organization. Intermediate level maintenance is to be performed by trained government repair specialists or contractors and is to include the replacement of refractory material and any other major maintenance required to ensure safe and reliable operation for a six-month deployment.

S5.10 Airborne noise shall meet the noise limits recommended in SNAME T&R Bulletin No. 3-37 that provides design guidance on shipboard airborne noise control.

S5.11 The system shall be free from vibration that could result in damage or the potential of damage to the ship structure, machinery, equipment, and systems, or interferes with the operation of the ship, its cargo systems, or any ship component. It shall have no resonant frequencies of its parts or structure below 40 Hz. The system shall be in accordance with MIL-STD-901C for Grade B shock.

S5.12 The incinerator shall be safe under both normal and unplanned conditions in accordance with the requirements of MIL-STD-882. As part of this study, a Failure Modes and Effects Criticality Analysis shall be performed to evaluate the impact and likelihood of all conceivable failures. This shall include as a minimum, accidental introduction of materials that are not recommended for processing and loss of any or all services.

S5.12.1 The following types of failures are not acceptable as part of the incinerator:

S5.12.1.1 Catastrophic failures that result in death or system loss and are of remote likelihood to occur.

S5.12.1.2 Critical failures that cause severe injury, illness, or major system damage and are of probable likelihood to occur.

S5.12.1.3 Marginal failures that cause minor injury or illness or system damage and are expected to occur frequently.

S5.12.2 The following failures shall be minimized to the greatest possible extent:

S5.12.2.1 Catastrophic failures that are of improbable likelihood to occur.

S5.12.2.2 Critical failures that are of occasional likelihood to occur.

S5.12.2.3 Marginal failures that are of probable likelihood to occur.

APPENDIXES

X1. LOCATION REQUIREMENTS FOR INCINERATORS

X1.1 Incinerators for sludge oil may be installed in the engine room or in a separate room. Incinerators for garbage installed in the engine room should receive due attention to size and location of the incinerator. If the incinerator is installed in a separate room outside the engine room, bulkheads and decks of this room are to be A-class boundaries insulated in accordance with the requirements for Category A machinery spaces, as defined by SOLAS 1974, as amended in Chapter II-2, Regulation 3. This requirement shall apply regardless of the type of vessel construction used (that is, Methods IC, IIC, IIIC as defined in SOLAS II-2, Regulation 42) and regardless of whether the vessel is required to meet SOLAS or to be approved or certified by the cognizant government authority.

X1.2 On certified vessels or those meeting SOLAS, both fire-detection and extinguishing systems must be approved by the cognizant government authority. Ventilation ducts should be capable of being closed by means of fire dampers, controlled from outside the incinerator room, of sufficient construction to maintain the A-class boundary. Emergency stop of oil burner and oil-booster pumps shall also be arranged outside the room.

X1.3 Flue gas-uptakes and surfaces of incinerators are not to be less than 500 mm (20 in.) from fuel, oil tanks, or accommodation bulkheads. Flue gas-uptake and exhaust pipe are to be insulated and located well away from electrical
installations and inflammable items. Exhaust pipes in the casing are to be led to the top of the funnel. Exhaust uptakes from incinerators, which are installed in separate rooms outside the engine room, are to be approved in each case.

X1.4 Incinerators and flue gas uptakes are to be located outside of hazardous areas as defined by the applicable rules.

X1.5 The flue lines of incinerating systems shall not open into the flues or exhaust lines of other equipment but must be arranged separately to the point of discharge.

X1.6 Garbage chutes shall comply with the same fire standards as incinerator rooms outside engine rooms.

**X2. INCINERATORS INTEGRATED WITH HEAT RECOVERY UNITS**

X2.1 The flue gas system, for incinerators in which the flue gas is led through a heat recovery unit (economizer), should be designed so that the incinerator can continue operation with the economizer coils dry. This may be accomplished with bypass dampers if needed.

X2.2 The incinerator unit should be equipped with a visual and audible alarm in case of loss of feed water.

X2.3 The gas side of the economizer should have equipment for proper cleaning. Sufficient access should be provided for adequate inspection of external heating surfaces.

**X3. FLUE GAS TEMPERATURE**

X3.1 When deciding upon the type of incinerator, consideration should be given as to what the flue gas temperature will be. The flue gas temperature can be a determining factor in the selection of materials for fabricating the stack. Special high-temperature material may be required for use in fabricating the stack when the flue gas temperatures exceed 413°C (775°F).

**X4. DESIGN FOR FUTURE RETROFITS OF AIR EMISSION CONTROL EQUIPMENT**

X4.1 Though not a requirement, it is recommended that incinerators be provisioned with an ability for future retrofits of air emission control equipment to accommodate emission standards for shipboard incinerators as they are developed.

X4.2 The Environmental Protection Agency (EPA) does not currently have emission standards for small shipboard incinerators as described in this specification. However, the EPA has indicated it intends to publish emission standards eventually. In addition, emission standards for state and local jurisdictions vary.

**X5. SPARK ARRESTORS**

X5.1 The incinerator should be so constructed or so equipped as not to permit from the exhaust the passage of spherical objects having a diameter larger than 13.7 mm (½ in.) nor block the passage of spherical objects having a diameter of less than 9.5 mm (⅜ in.).

X5.2 Means should be provided for securely attaching the spark arrestors to chimneys to provide adequate support and prevent movement of the arrestor.

X5.3 Means should be provided to replace spark screens.

**X6. HUMAN ENGINEERING**

X6.1 The system should comply with Practice F 1166.

X6.2 The incinerator should conform to human engineering principles to the degree that it can be operated and maintained by a 152-cm (5-ft) tall person as well as a 185-cm (6-ft 1-in.) tall person.

X6.3 Its design should also reflect system and personnel safety factors, including the elimination or minimization of the potential for human error during operation and maintenance, under both routine and nonroutine or emergency conditions. Machinery, systems, equipment, and fixtures should be intrinsically safe as far as practicable, and in the event of failure, should fail to a safe mode.

X6.4 Man-machine interfaces should minimize both the potential for and the consequence of human error.

X6.5 The level of training required for operating personnel should be no more than 2 h of on-the-job training; training required for maintenance personnel should be no more than 5 h.
X7. ASH/SLAG COLLECTION

X7.1 The incinerator should provide for the safe collection and removal of both bottom and fly ash from the incinerator with minimal interference to the combustion process. The incidental introduction of metal or glass into the incinerator should not negatively impact incinerator operation, maintenance, or the ash removal processes.

X7.2 The process for the collection and removal of bottom and fly ash or slag can be either of the following: (1) automatic and continuous without requiring shutdown or (2) manual and require system shutdown. In either case, operator handling of ash should be required to occur no more than once per day.

X7.3 For automatic ash removal systems, the ASTM interlock requirements to prevent ash removal until the combustion chamber cools to 220°C (428°F) is hereby waived, provided the automated ash removal process does not create hazardous or unsafe conditions and the combustion zone is isolated from the outside work space at all times.

X7.4 The incinerator architecture should not require undue exposure of the operator to temperatures above 60°C (140°F), ash, hazardous gases, or other incinerator by-products during the process of transferring ash or slag into a container for storage or disposal.

X7.5 The ash or slag will be transferred to and stored in 55-gal drums or other size containers dependent on type and size of incinerator and size of ship it is installed upon. The temperature of the ash being transferred should be less than 220°C (428°F).

X7.6 There should be no obstructions around the ash removal door that can cause accidental exposure of maintenance personnel to ash either directly or through the air.

X8. PROCESS MONITORING

X8.1 The system should provide for sufficient process monitoring and the automated controls necessary to maintain the set point operating conditions.

X8.2 Set points for low/high temperature, carbon monoxide, oxygen, smoke opacity, and any other parameter required by the manufacturer to control the incineration process are to be determined by the manufacturer.

X8.3 The incinerator control/operator interface should clearly communicate all information to the operator that is required to ensure efficient and safe operation of the incinerator process.

X9. EMISSION REQUIREMENTS FOR SHIPBOARD INCINERATORS

X9.1 An IMO Type Approval Certificate should be required for each shipboard incinerator. To obtain such certificate, the incinerator should be designed and built to an IMO-approved standard. Each model should go through a specified type approval test operation at the factory or an approved test facility, and under the responsibility of the administration.

X9.2 The Type Approval Test should include measuring of the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit or Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum capacity</td>
<td>kW or kcal/h</td>
</tr>
<tr>
<td>Pilot fuel consumption</td>
<td>kg/h of specified waste</td>
</tr>
<tr>
<td>O₂ average in combustion chamber/zone</td>
<td>kg/h per burner</td>
</tr>
<tr>
<td>CO average in flue gas</td>
<td>%</td>
</tr>
<tr>
<td>Soot number average</td>
<td>mg/MJ</td>
</tr>
<tr>
<td>Combustion chamber flue gas outlet temperature average</td>
<td>Bacharach or Ringelman Scale</td>
</tr>
<tr>
<td>Amount of unburned components in ashes</td>
<td>°C</td>
</tr>
<tr>
<td>% by weight</td>
<td></td>
</tr>
</tbody>
</table>

X9.3 Duration of Test Operation:

For sludge oil and solid waste burning 6 to 8 h

X9.4 Fuel/Waste Specification for Type Approval Test (% by Weight):

<table>
<thead>
<tr>
<th>Sludge oil consisting of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 % sludge oil from heavy fuel oil</td>
</tr>
<tr>
<td>5 % waste lubricating oil</td>
</tr>
<tr>
<td>20 % emulsified water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solid waste (Class 2) consisting of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 % food waste</td>
</tr>
<tr>
<td>50 % rubbish containing approximately 30 % paper, 40 % cardboard, 10 % rags, and 20 % plastic. This mixture will have up to 50 % moisture and 7 % incombustible solids.</td>
</tr>
</tbody>
</table>

Classes of Waste:

Class 0 Trash, a mixture of highly combustible waste such as paper, cardboard, wood boxes, and combustible floor sweepings, with up to 10 % by weight of plastic bags, coated paper, laminated paper, treated corrugated cardboard, oil rags, and plastic or rubber scraps. This type of waste contains up to 10 % moisture, 5 % incombustible solids, and has a heating value of about 19 700 kJ/kg as fired.

Class 1 Rubbish, a mixture of combustible waste such as paper, cardboard, cartons, wood scrap, foliage, and combustible floor sweepings. The mixture contains up to 20 % by weight of galley or cafeteria waste, but contains little or no treated papers, plastic, or rubber wastes. This type of waste contains 25 % moisture, 10 % incombustible solids, and has a heating value of about 15 100 kJ/kg as fired.
Class 2  Refuse, consisting of approximately even mixture of rubbish and garbage by weight. This type waste is common to passenger ships’ occupancy, consisting of up to 50 % moisture, 7 % incombustible solids, and has a heating value of about 10 000 kJ/kg as fired.

Class 3  Garbage, consisting of animal and vegetable wastes from restaurants, cafeterias, galleys, sick bay, and like installations. This type of waste contains up to 70 % moisture, up to 5 % incombustible solids, and has a heating value range from about 2300 kJ/kg as fired.

Class 4  Aquatic life forms and animal remains, consisting of carcasses, organs, and solid organic wastes from vessels carrying animal-type cargo, consisting of up to 85 % moisture, 5 % incombustible solids, and having a heating value range from about 2300 kJ/kg as fired.

Class 5  By-product waste, liquid or semiliquid, such as tar, paints, solvents, sludge, oil, waste oil, and so forth, from shipboard operations. The Btu values must be determined by the individual materials to be destroyed.

Class 6  Solid by-product waste, such as rubber, plastics, wood waste, and so forth, from industrial operations. The Btu values must be determined by the individual materials to be destroyed.

Calorific values  

<table>
<thead>
<tr>
<th>Material</th>
<th>kJ/kg</th>
<th>kcal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable and putrescibles</td>
<td>5 700</td>
<td>1360</td>
</tr>
<tr>
<td>Paper</td>
<td>14 300</td>
<td>3415</td>
</tr>
<tr>
<td>Rag</td>
<td>15 500</td>
<td>3700</td>
</tr>
<tr>
<td>Plastics</td>
<td>36 000</td>
<td>8600</td>
</tr>
<tr>
<td>Oil sludge</td>
<td>36 000</td>
<td>8600</td>
</tr>
</tbody>
</table>

Densities  

<table>
<thead>
<tr>
<th>Material</th>
<th>kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper (loose)</td>
<td>50</td>
</tr>
<tr>
<td>Refuse (75 % wet)</td>
<td>720</td>
</tr>
<tr>
<td>Dry rubbish</td>
<td>110</td>
</tr>
<tr>
<td>Scrap wood</td>
<td>190</td>
</tr>
<tr>
<td>Wood sawdust</td>
<td>220</td>
</tr>
</tbody>
</table>

Density of loose general waste generated on board ship will be about 130 kg/m³.

Reference: Waste classification from Incinerator Institute of America.

X9.5  Required Emission Standards to be Verified by Type Approval Test:

- O₂ in combustion chamber 6 to 12 %
- CO in flue gas maximum average 200 mg/MJ
- Soot number maximum average Bacharach 3 or Ringelman 1
- Unburned components in ash residues maximum 10 % by weight
- Combustion chamber flue gas outlet temperature range 850–1 200°C

A high temperature in the actual combustion chamber/zone is an absolute requirement to obtain a complete and smoke-free incineration, including that of plastic and other synthetic materials while minimizing dioxin, VOC (volatile organic compounds), and emissions.

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1. Scope

1.1 This guide covers metallic abrasive blasting to descale the interior of carbon steel pipe.

1.2 This guide is recommended for use in conjunction with an abrasive reclamation system.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
2.2 SAE Standards:
J444 Cast Shot and Grit Size Specifications for Peening Cleaning
J827 Cast Steel Shot
2.3 Other Documents:
SSPC SP10 Surface Preparation Specifications
SSFS 20-66 Standard Specification for Cast Steel Abrasives

3. Significance and Use

3.1 The maximum length and minimum diameter of the pipe shall be determined by the capacity of the blast equipment used.

3.2 This guide is recommended for removing mill scale, rust scale, paints, zins, and oxides.

4. General Requirements

4.1 Before blasting, pipe shall be dry and free of slag and weld spatter which would not be removed by abrasive blasting. Pipe shall also be free of loose dust and debris which might hamper the effectiveness of abrasive blasting.

4.2 Abrasive blasting shall be accomplished in a dry area with the ambient air condition such that condensation does not occur.

4.3 Shot and blasting equipment shall be stored at a temperature not less than −13°C (10°F) above the dew point of the surrounding area.

4.3.1 Abrasive reclamation system shall include a filtration system capable of removing oxides, debris, dust, shot/grit fragments, and fines.

4.4 Compressed air system shall be equipped with moisture removal devices capable of reducing the dew point of the air at the nozzle to −18°C (approximately 0°F) or less.

4.5 Hoses shall have the maximum practical diameter and shall be as short as possible.

4.6 Nozzles shall have the maximum possible aperture as determined by the capacity of the blast equipment and as limited by the pipe diameter.

4.7 Internal pipe cleaning nozzle assemblies are commercially available and shall be used where required.

4.7.1 Internal pipe cleaning nozzle assemblies shall include a carriage which is capable of centering the nozzle concentrically in the pipe being blasted and a nozzle which is capable of producing a consistent 360° blast pattern.

4.7.2 Diagrams of some commercially available internal pipe cleaning assemblies are provided in Figs. 1-4.

4.7.3 If a lance is required, it shall be at least as long as the pipe being blasted.

4.8 Blasting shall be accomplished using an abrasive mixture of cast steel shot and grit, or with iron shot or grit.

4.8.1 Iron or grit may be used if desired.

4.8.2 Cast steel shot and grit mixtures shall be sized in accordance with SAE J444.

4.8.3 Reclaimed shot and grit shall be of the same quality as the original material.
4.9 Cast steel shot shall be manufactured in accordance with SAE J827 and tempered to a hardness of 40-50 Rockwell C in accordance with Test Methods E 18 (see Table 1).

4.10 Cast steel grit shall be manufactured in accordance with SFSA 20-66 and tempered to a hardness of 55-65 Rockwell C in accordance with Test Methods E 18 (see Table 2).

4.11 Shot and grit size shall be determined by the following criteria:

4.11.1 Smaller shot and grit produces more impacts per inch and is therefore more effective for removing paints and corrosion products.

4.11.2 Larger shot and grit produces more kinetic energy per impact and is therefore more efficient for removing heavier deposits such as mill scale.

4.12 If surface type and profile is specified, abrasive shall be selected using the following criteria:

4.12.1 Shot produces a wavy rounded surface profile which increases coating area coverage.

4.12.2 Grit produces a sharp angular profile which forms a better anchor pattern for most coatings.

4.12.3 Table 3 lists some typical maximum profiles produced by some commercial abrasive media.\(^5\)

4.13 Blasting shall be accomplished with a minimum of 620-kPa (90-psi) dry air pressure at the nozzle.

---

**TABLE 1 Steel Shot and Grit Specifications\(^{A,B}\)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Shot</th>
<th>Grit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size:</td>
<td>All material is screened to meet or exceed SAE J444 and SFSA 20-66.</td>
<td></td>
</tr>
<tr>
<td>Chemistry:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>0.85 to 1.20 %</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>0.60 to 1.00 %</td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td>0.50 to 1.00 %</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>&lt;0.05 %</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>&lt;0.05 %</td>
<td></td>
</tr>
<tr>
<td>Microstructure:</td>
<td>Uniformly tempered martensite, with fine, well-distributed carbides, if any. Carbide networks, transformation products, decarburized surfaces, inclusions, and quench cracks are undesirables.</td>
<td></td>
</tr>
<tr>
<td>Hardness:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commonly used structural steel(^C)</td>
<td>40 to 50 RC (^D)</td>
<td>40 to 50 RC (^D)</td>
</tr>
</tbody>
</table>

\(^A\)Courtesy of Steel Structures Painting Council.

\(^B\)It is extremely important that contractual documents which specify abrasive to be used clearly designate the abrasive by size and by hardness.

\(^C\)Both cast steel shot and grit of hardmesses in the range from 30 to 66 Rockwell C may be purchased. However, the abrasives of less than 40 RC and greater than 60 RC are generally used for applications other than surface preparation of structural steel.

\(^D\)Abrasive manufacturers identify steel grit by designations which include two or more prefix letters, followed by the number size. Prefix letters are different for each of the abrasive suppliers for any given hardness range.

**TABLE 2 Types of Steel Abrasives Most Commonly Used for Various Structural Steel Blast Cleaning Operations\(^A\)**

<table>
<thead>
<tr>
<th>Abrasive Type</th>
<th>Size Range(^D)</th>
<th>Hardness (RC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot</td>
<td>S170 to S390</td>
<td></td>
</tr>
<tr>
<td>Fabricated new steel X</td>
<td>S170 to S390</td>
<td></td>
</tr>
<tr>
<td>Heat-treated steel X</td>
<td>G50 to G25</td>
<td></td>
</tr>
<tr>
<td>Heavy steel plate X</td>
<td>S230 to S390</td>
<td></td>
</tr>
<tr>
<td>Corroded steel X</td>
<td>G50 to G25</td>
<td></td>
</tr>
<tr>
<td>Weld scale X</td>
<td>S170 to S280</td>
<td></td>
</tr>
<tr>
<td>Brush blast X</td>
<td>S170 to S280</td>
<td></td>
</tr>
<tr>
<td>Repair work X</td>
<td>G50 to G40</td>
<td></td>
</tr>
<tr>
<td>Maintenance X</td>
<td>G80 to G18</td>
<td></td>
</tr>
</tbody>
</table>

\(^A\)Courtesy of Steel Structures Painting Council.

\(^D\)Size Range refers to working mix (operating mix) for recirculating abrasive blast systems. For additional information see Vol 1, Chapter 2 of the “Steel Structures Painting Manual.”
4.14 If an abrasive reclamation system is used, it shall be capable of filtering the used abrasive and returning the usable mixture.

5. Procedure

5.1 Pipe shall be located as close as possible to the blast equipment and blown clean of loose debris before blasting.

5.2 Pipe with an interior diameter of 100 mm (approximately 4 in.) or larger may be manually blasted from both ends if both ends are accessible and the pipe length configuration and equipment capabilities are such that the blasted surface is consistent throughout the pipe.

5.3 If pipe is inaccessible from one end, bent, or too long to be hand blasted, it will be necessary to use an internal pipe cleaning nozzle assembly.

5.3.1 Nozzle assembly shall be placed inside the pipe in a manner such that the nozzle is concentric with the pipe.

5.3.2 Nozzle assembly shall then be passed through the entire length of the pipe at a constant rate.

5.4 Extreme caution shall be used in all the blasting operations to avoid unnecessary removal of parent metal.

5.5 When blasting is completed, pipe shall be blown clean of residual debris and visually inspected in accordance with Standard D 2200 and reblasted as required.

5.6 Interior of pipe shall then be coated when specified. Coatings should be applied to freshly blasted surface before any rusting or contamination should occur.

6. Workmanship, Finish, and Appearance

6.1 Pipe shall be blasted to a near white finish in accordance with SSPC SP10, or as otherwise specified.

7. Keywords

7.1 abrasive blasting; carbon steel pipe; descaling; interior descaling; marine technology; metallic abrasive; pipe descaling; ships

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**TABLE 3** Typical Maximum Profiles Produced by Some Commercial Abrasive Media

<table>
<thead>
<tr>
<th>Abrasive—Steel Abrasives</th>
<th>Maximum Particle Size NBS Screen No.</th>
<th>Typical Profile, Height (mils), max avg max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot S230 − No. 18 + No. 20</td>
<td>2.9 ± 0.2</td>
<td>2.2 ± 0.3</td>
</tr>
<tr>
<td>Shot S280 − No. 16 + No. 18</td>
<td>3.5 ± 0.3</td>
<td>2.5 ± 0.4</td>
</tr>
<tr>
<td>Shot S330 − No. 14 + No. 16</td>
<td>3.8 ± 0.4</td>
<td>2.8 ± 0.5</td>
</tr>
<tr>
<td>Shot S390 − No. 12 + No. 14</td>
<td>4.6 ± 0.5</td>
<td>3.5 ± 0.7</td>
</tr>
<tr>
<td>Grit G50 − No. 25 + No. 30</td>
<td>2.2 ± 0.3</td>
<td>1.6 ± 0.3</td>
</tr>
<tr>
<td>Grit G40 − No. 18 + No. 20</td>
<td>3.4 ± 0.4</td>
<td>2.4 ± 0.5</td>
</tr>
<tr>
<td>Grit G25 − No. 16 + No. 18</td>
<td>4.6 ± 0.5</td>
<td>3.1 ± 0.7</td>
</tr>
<tr>
<td>Grit G14 − No. 10</td>
<td>6.5 ± 0.8</td>
<td>5.1 ± 0.9</td>
</tr>
</tbody>
</table>

*Courtesy of Steel Structures Painting Council.*

Profile heights shown for steel abrasives were produced with conditioned abrasives of stabilized operating mixes in recirculating abrasive blast cleaning machine. Profile heights produced by new abrasives having screen analyses shown in SAE J444 will be appreciably higher.

Cast steel shot: Hardness 40 to 50 Rockwell C.

Cast steel grit: Hardness 55 to 60 Rockwell C.
Standard Practice for Installation Procedures of Vinyl Deck Coverings on Portable Plates in Electrical and Electronic Spaces

1. Scope

1.1 This practice covers the acceptable method for installing insulated deck covering on portable deck plates.
1.2 This deck covering shall be installed, in way of the electrical and electronic spaces, for marine use.
1.3 The values stated in SI (metric) units are to be regarded as the standard. The values in parentheses are for information only.
1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
   D 1338 Practice for Working Life of Liquid or Paste Adhesives by Consistency and Bond Strength
   D 2393 Test Method for Viscosity of Epoxy Resins and Related Components
   D 4389 Specification for Finished Glass Fabrics Woven from Rovings
   F 150 Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring

2.2 Other Documents:
   Steel Structural Painting Council  SP-11

3. Requirements

3.1 Operations Area—Typical areas for application of the electric insulating deck covering are:
3.1.1 The operating areas in front and rear of power and lighting switchboards, interior-communication switchboards, test switchboards, fire-control switchboards, and shipboard announcing-systems amplifiers and control panels.
3.1.2 The area around electronic equipment which may be contacted by personnel in servicing or tuning energized equipment.
3.1.3 Vinyl sheets should be confined to the minimum deck areas (generally 0.9 m (3 ft) wide) surrounding the apparatus necessary to prevent electric shock, and should, unless otherwise specified, be cemented to the deck in lieu of other specified deck coverings.

3.2 Installation—Vinyl Sheets:
3.2.1 Installation of deck covering shall be in accordance with Figs. 1-7, using vinyl sheet and fiberglass binding strips (see Fig. 1 and Fig. 5).

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1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.03 on Outfitting.

2 Annual Book of ASTM Standards, Vol 15.06.

3 Discontinued; See 1991 Annual Book of ASTM Standards, Vol 08.02.


6 Available from Steel Structures Painting Council (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656.

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3.2.2 Vinyl sheets and fiberglass sheets shall be united at the edges in a rabbet joint as shown (see Fig. 7), and such that the fiberglass overlaps at all joints. All rabbeted surfaces shall be smooth and corners sharp and square, such that at installation the overlapping areas fit firmly and flush. Vinyl shall meet requirements and tests provided in Test Method F 150.

3.3 **Adhesive:**

3.3.1 Vinyl sheets shall be secured to each portable plate with adhesive. Adhesive should not extend beyond edges of vinyl sheet.

3.3.2 Silicone compound, with 1% liquid catalyst, should be applied between lapping areas in accordance with Test Method D 1338.

3.4 **Fiberglass**—Glass fiber base, epoxy resin sheets furnished under this specification (Fig. 1 and Fig. 5), shall be a product consisting of plies or layers of cloth or nonwoven parallel aligned fibers bonded with an epoxy resin compound, in accordance with Specification D 4389.

3.5 **Fastening with Nylon Screws**—Fiberglass binding strips shall be secured to the deck with nylon screws. A 76-mm (3-in.) wide strip over joints between portable plates shall be fastened with a double row of screws. A 38-mm (1½-in.) wide strip or shape to suit at deck edges shall be fastened with a single row of screws, spacing between screws not to exceed 127 mm (5 in.) center-to-center and located to clear deck plate screws. (See Fig. 7.)

3.6 **Exposed Areas Treated with Epoxy:**

3.6.1 Before the epoxy is applied, the surface to be covered should be (a) cleaned with a solvent, and (b) further treated in accordance with Steel Structural Painting Council SP-11.

3.6.2 Epoxy resin shall be applied to the exposed vertical lip of deck edges on stanchions, to approximately 305 mm (12 in.) above deck, after all other deck covering work has been
completed. Application of epoxy shall be by brush to approximately 1.5-mm (1/16-in.) thickness, and in accordance with Test Method D 2393. (For location of epoxy to be applied, see Fig. 3 and Fig. 4.)

4. Keywords
4.1 deck covering; electrical space; electronic space; insulated deck covering; marine technology; portable deck plate; ship; vinyl deck covering

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Standard Practice for
Use of SI (Metric) Units in Maritime Applications (Committee F-25 Supplement to IEEE/ASTM SI 10)1

INTRODUCTION

The International System of Units (SI) was developed by the General Conference on Weights and Measures (CGPM), which is an international treaty organization. The abbreviation SI, derived from the French “Le Système International d’Unités,” is used in all languages.

On Dec. 23, 1975, Public Law 94-168, “The Metric Conversion Act of 1975,” was signed by President Ford, committing the United States to a coordinated voluntary conversion to the metric system of measurement. The Act specifically defines the “metric system of measurement” as “the International System of Units as established by the General Conference on Weights and Measures in 1960, and as interpreted or modified for the United States by the Secretary of Commerce.”

On Aug. 23, 1988, President Reagan signed into law P.L. 100-576, the Omnibus Trade and Competitiveness Act of 1988. The Act specifies that “metric” means the modernized metric system (SI). The Act then amended the Metric Conversion Act of 1975 to designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce.

This practice will help obtain uniform SI practice in the marine industry by providing a technical reference for the International System of Units (SI). The practice is not intended to cover all aspects of SI usage, but to serve as a ready reference especially tailored to the operating needs of the industry. For further information on SI usage and conversion factors for units not found herein, refer to IEEE/ASTM SI 10, upon which this practice is based.2 In the event of a conflict, IEEE/ASTM SI 10 shall take precedence. (See also NIST Special Publication 811.)3 Hardware and other standards in SI are currently being developed.

1. Scope

1.1 This practice covers the use of SI, which is comprised of base and derived SI units. Also discussed are non-SI units that have been accepted and recognized by the CGPM as appropriate for limited use or time. Basic rules for style and usage of SI are set forth, as well as methods for conversion from non-SI units to SI units. Tables of quantities used by the marine industry are included, with present units and conversion factors given.

2. Referenced Documents

2.1 ASTM Standards:

2.2 NIST Publications:
NIST Special Publication 811 Guide for the Use of the International System of Units (SI)3
NIST Special Publication 330 The International System of Units (SI)3

3. Terminology

3.1 Definitions:

3.1.1 quantity, n—measurable attribute of a physical phenomenon.

3.1.2 SI, n—The universally accepted abbreviation for the International System of Units as defined in the document Le Système International d’Unités, 6th Edition, published by the International Bureau of Weights and Measures (BIPM), Sevres, France, 1991, and as interpreted and modified for the United...
3.1.3 unit, n—reference value of a given quantity as defined by CGPM Resolution or ISO standards. There is only one unit for each quantity in SI.

3.2 Definitions of Terms Specific to This Standard:
3.2.1 coherent system of units—a system of units of measurement in which a small number of base units, defined as dimensionally independent, are used to derive all other units in the system by rules of multiplication and division with no numerical factors other than unity.

4. The Concept of SI
4.1 The International System of Units (SI) was developed to provide a universal, coherent, and preferred system of units for world-wide use and appropriate to the needs of modern science, technology, and international commerce.

4.2 The principal features of SI are:
4.2.1 There is one and only one unit for each quantity.
4.2.2 The system is fully coherent.
4.2.3 Designated prefixes can be attached to units to form multiples and submultiples of ten raised to a power. Use of the prefixes provides for convenient numerical values when the magnitude of a quantity is stated, and avoids the need for many insignificant zeroes. The system is decimal, the same as the commonly used numerical system.
4.2.4 Units and prefixes are represented by standardized and internationally recognized symbols.
4.2.5 A few specifically accepted non-SI units are permitted in conjunction with SI.
4.4 SI units, acceptable non-SI units, and prefixes are discussed in Sections 5 and 6.

5. SI Units
5.1 SI includes two classes of units:
5.1.1 Base units and
5.1.2 Derived units.
5.2 Base Units—The International System of Units is based on seven base units, listed in Table 1, which by convention are regarded as dimensionally independent.
5.3 Derived Units—Derived units are formed by the algebraic combination of base units and derived units. Derived units with special names are listed in Table 2.
5.4 Temperature—The SI unit of thermodynamic temperature is the kelvin, and this unit is properly used for expressing thermodynamic temperature and temperature intervals. The thermodynamic temperature and temperature intervals. The

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TABLE 1 SI Base Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Base SI Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>metre</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Thermodynamic temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>

TABLE 2 SI Derived Units with Special Names

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name of Derived SI unit</th>
<th>Symbol</th>
<th>Expressed in Terms of Base and Derived SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle, plane</td>
<td>radian</td>
<td>rad</td>
<td>mm = 1</td>
</tr>
<tr>
<td>Angle, solid</td>
<td>steradian</td>
<td>Sr</td>
<td>m²/m² = 1</td>
</tr>
<tr>
<td>Frequency</td>
<td>hertz</td>
<td>Hz</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>Force</td>
<td>newton</td>
<td>N</td>
<td>kg/m/s²</td>
</tr>
<tr>
<td>Pressure, stress</td>
<td>pascal</td>
<td>Pa</td>
<td>N/m²</td>
</tr>
<tr>
<td>Energy, work, quantity of heat</td>
<td>joule</td>
<td>J</td>
<td>N·m</td>
</tr>
<tr>
<td>Power, radiant flux</td>
<td>watt</td>
<td>W</td>
<td>J/s</td>
</tr>
<tr>
<td>Electric charge, quantity of electricity</td>
<td>coulomb</td>
<td>C</td>
<td>A·s</td>
</tr>
<tr>
<td>Electric potential, potential difference, electromotive force</td>
<td>volt</td>
<td>V</td>
<td>W/A</td>
</tr>
<tr>
<td>Electric capacitance</td>
<td>farad</td>
<td>F</td>
<td>C/V</td>
</tr>
<tr>
<td>Electric resistance</td>
<td>ohm</td>
<td>Ω</td>
<td>V/A</td>
</tr>
<tr>
<td>Electric conductance</td>
<td>siemens</td>
<td>s</td>
<td>A/V</td>
</tr>
<tr>
<td>Magnetic flux</td>
<td>weber</td>
<td>Wb</td>
<td>V·s</td>
</tr>
<tr>
<td>Magnetic flux density</td>
<td>tesla</td>
<td>T</td>
<td>Wb/m²</td>
</tr>
<tr>
<td>Inductance</td>
<td>henry</td>
<td>H</td>
<td>Wb/A</td>
</tr>
<tr>
<td>Luminous flux</td>
<td>lumen</td>
<td>lm</td>
<td>cd·s⁻¹</td>
</tr>
<tr>
<td>Illuminance</td>
<td>lux</td>
<td>lx</td>
<td>lm/m²</td>
</tr>
<tr>
<td>Celsius temperature</td>
<td>degree Celsius</td>
<td>°C</td>
<td>K</td>
</tr>
<tr>
<td>Activity (of a radionuclide)</td>
<td>becquerel</td>
<td>Bq</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>Absorbed dose</td>
<td>gray</td>
<td>Gy</td>
<td>J/kg</td>
</tr>
<tr>
<td>Dose equivalent</td>
<td>sievert</td>
<td>Sv</td>
<td>J/kg</td>
</tr>
</tbody>
</table>

A See 5.4.

degree Celsius is equivalent to kelvin with a different zero point on the scale. Celsius temperature  is equal to kelvin temperature minus 273.15 ( = T − T₀, where T = Kelvin and T₀ = 273.15).

5.5 SI Prefixes—The prefixes and symbols shown in Table 3 are used to form decimal multiples and submultiples of SI units.

5.6 Selection of Prefixes:
5.6.1 A prefix should be selected so that the numerical value of the unit expressed will fall between 0.1 and 1000. An exception to this rule arises in the preparation of tables of values of the same quantity and in discussion of such values within a given context, when it is better to use the same unit multiple. Also, for certain applications, one particular multiple will customarily be used; for example, use of the millimetre for linear dimensions in engineering drawings.

5.6.2 Compound prefixes should not be used; for example, use GJ, not kMJ.

5.6.3 Prefixes should preferably not be used in the denominator of compound units. Example, use V/m not mV/mm. The exception is the kilogram as it is the base unit: J/kg, not kJ/g.

5.6.4 Errors in calculation may be avoided by using powers of ten with the units rather than prefixes.
6. Non-SI Units in Use with SI

6.1 Units in Use with SI—Certain units that are not SI have been accepted for use with SI units. Some of these units, currently recognized as acceptable for use with SI, are listed in Table 4 and Table 5.

6.2 Time—The SI unit of time is the second. This unit is preferred and should be used when practical, particularly in technical calculations.

6.3 Plane Angle—The SI unit of plane angle is the radian. When the radian is not a convenient unit, the degree should be used with decimal submultiples. Minutes and seconds should be used only when required (as in navigation).

6.4 Area—The SI unit of area is the square metre. The hectare (ha) is a special name for square hectometre (hm²). Large land or water areas are generally expressed in hectares or in square kilometres.

6.5 Volume—The SI unit of volume is the cubic metre. The cubic metre, or one of its multiples or submultiples, is preferred for all applications. The special name litre has been approved by the CGPM for the cubic decimetre.

6.6 Mass—The SI unit of mass is the kilogram. The kilogram, or one of the multiples or submultiples formed by attaching an SI prefix to gram, is preferred for all applications. For large masses (such as have been expressed in tons), the megagram is the appropriate unit. The term metric ton should be restricted to commercial and maritime usage, and no prefixes should be used with it. To avoid confusion, use of the term “tonne” to indicate metric ton is discouraged.

7. Mass, Force, and Weight

7.1 SI, being coherent, is different from the older metric systems in the use of distinctly separate units for mass and force. In SI, the unit of force, the newton (N), is derived as the laws of physics dictate, instead of being related to gravity, and is defined as being equal to the force that imparts an acceleration of unit (1 m/s²) to a unit mass, the kilogram (kg).

7.1.1 Mass—The mass of a body is a measure of its inertia, that is, its resistance to a change in its motion. In practical terms, mass represents the quantity of matter in a body (not to be confused with amount of substance expressed in moles). The SI unit of mass is the kilogram (kg).

7.1.2 Force—Force is the mechanical action on a body resulting from physical contact with another body or the action resulting from gravitational or electromagnetic fields. The SI unit of force is the newton (N).

7.1.3 Weight—The weight W of a body is the effective gravity force acting on it and equals the product of its mass m and the local acceleration of free fall, g, so that W = mg. In SI, weight is measured in newtons (N). Because the acceleration of gravity (the acceleration of free fall) varies slightly over the surface of the earth, the weight of a body varies accordingly, whereas its mass is a constant.

7.1.4 Discussion—The existence of clearly separate units for mass and force in SI contrasts with the widespread use of
the units lb and kg for both mass and force. Whereas the word “weight” has been commonly used when mass is intended or implied, especially in commerce and everyday life, this use should in time disappear with growing acceptance and use of SI units, and the word mass (rather than weight) will be used when mass is meant. The use of weight for mass should be avoided altogether in scientific and technical communication.

8. Rules for Style and Usage of SI

8.1 Rules for Writing Unit Symbols:

8.1.1 Particular care must be taken to use the correct symbols for units and prefixes (for example, K for kelvin, k for kilo, M for mega, m for milli). When using systems with limited character sets, as in Telex transmission or computer printout, the standard symbols cannot be used. For these purposes, refer to ISO 2955 or ANSI X3.50.

8.1.2 Unit symbols are symbols and do not vary from singular to plural.

8.1.3 Unit symbols should be printed in roman (upright) type, regardless of the type style used in the surrounding text.

8.1.4 Unit symbols are not followed by a period except when used at the end of a sentence.

8.1.5 The numerical value associated with a symbol should be separated from that symbol by a space. For example, 25.4 mm, not 25.4mm. The only exception to this rule is that no space is left between the symbols (for example, N·m).

8.1.6 Unit symbols should be used in preference to the unit names except when a number written out in words precedes the unit; for example “seven metres” not “seven m.”

8.2 Rules for Writing Unit Names:

8.2.1 The first letter of a unit name is not capitalized except at the beginning of a sentence or in capitalized material such as a title.

8.2.2 Plurals of unit names are formed in the ordinary manner, except for lux, hertz, and siemens, which remain the same.

8.2.3 No space or hyphen is used between a prefix and the unit name; for example, kilonewton.

8.3 Product, Quotient, and Powers:

8.3.1 To indicate the product of units when using their names, a space is left between the names (for example, newton metre). When using symbols, a centered dot should be placed between the symbols (for example, N·m).

8.3.2 To indicate the quotient of units when using their names use the word “per” (for example, metres per second). When using unit symbols, a solidus (/) or negative exponent should be used (for example, m/s or m·s⁻¹). Do not use more than one solidus in the same expression. Use parentheses to avoid any ambiguity (consider m/s·A can mean m/(s·A) or (m/s)·A).

8.3.3 To indicate powers when using unit names, the words “square,” “cubic,” “squared,” “cubed,” and so forth should be used (for example, square metre, second squared). When using unit symbols, powers are indicated by the use of an exponent (for example, m³).

8.4 Numbers:

8.4.1 At present, the period will be used for the decimal marker. For numbers of less than one, a zero should precede the decimal; for example, 0.964.

8.4.2 Recommended international practice calls for the use of a space to separate large numbers into groups of three. Do not use a comma. The digits should be separated into groups of three counting from the decimal point toward the left and the right, and using a small space to separate the groups. In numbers of four digits, the space is usually not necessary except to provide uniformity in tables, columns, and so forth. For example, 16 390, 1.828 8 or 1.8288, 4 536 or 4536.

9. Conversion and Rounding Methods

9.1 Soft Conversion—Soft conversion is the process of changing the non-SI measurement language to equivalent SI units within acceptable measurement tolerances without changing the physical configuration. In other words, the item described is the same item both before and after conversion.

9.2 Hard Conversion—Hard conversion is the change of design and use of measures to SI as if non-SI units did not exist, namely the use of integers and round numbers, in SI, as the basis of design. Although the term is in general use, it is technically incorrect when applied to specific items because no “conversion” takes place; rather, a new item, designed in SI units (requiring a new identification), is created to replace the old item.

9.3 Conversion Factors—Table 6 contains conversion factors for units commonly used in the marine field.

9.4 Precision—When converting, care must be given to the precision desired. The number of significant digits retained in the answer should be such that accuracy is neither sacrificed nor exaggerated. Specified quantities should first be multiplied by the exact conversion factor and then rounded to the appropriate number of significant digits. Do not round either the conversion factor or the quantity before performing the multiplication, as accuracy would be reduced. Use appropriate prefixes to eliminate insignificant, leading, or trailing zeroes.

9.5 Rounding—The rounding required by conversion and computation in SI units should be done using the following rules for the three general cases:

9.5.1 Where the digit immediately following the last digit to be retained is less than 5, the last digit retained should not be changed.

9.5.2 Where the digit immediately following the last digit to be retained is greater than 5 (or it is a 5 followed by at least one digit other than 0), the last digit should be increased by one.

9.5.3 Where the digit immediately following the last digit to be retained is exactly 5 (or it is a 5 followed by only zeroes), the last digit retained is not changed if it is even, and if it is odd it should be increased by one. For example, 4.365 00 becomes 4.36 when rounded to three digits. 4.355 00 also becomes 4.36 when rounded to three digits.

9.5.4 The above rules provide an additional observation about significant digits. The least significant digit (the last digit retained in the rounding process) cannot be considered more precise than 0.5 of its place value.
10. Accuracy of Conversion

10.1 It is important, in any conversion, to determine the accuracy of the original value and the repeatability of the converted value. Where interchangeability of converted values is required, IEEE/ASTM SI 10 should be consulted for exact procedures which will establish limits to the errors resulting from conversion calculations.

11. Special Ratios

11.1 Two special ratios\(^5\) are used in the maritime industry. These ratios are speed-length ratio, \(V/\sqrt{L}\), and displacement-length ratio, \(\Delta/(0.01 L)^3\)

where:
\(V = \) speed in knots,
\(L = \) length in feet, and
\(\Delta = \) displacement in long tons.

11.2 When using SI units, the speed-length ratio should be replaced by Froude number, \(v / (gL)^{0.5}\), in coherent units, where:
\(v = \) velocity,
\(g = \) gravitational acceleration, and
\(L = \) the ship’s length.

11.3 Similarly, the displacement-length ratio should be replaced by the volumetric coefficient, \(\pi / L^3\), in coherent units, where:
\(\pi = \) the underwater volume of the hull and
\(L = \) the ship’s length.

11.4 Speed-length ratio and displacement-length ratio are in common use because they have convenient values in their dimensional form. For example, \(V/\sqrt{L} = 1\) is significant from a wave resistance viewpoint. Using SI units would cause the numerical values of speed-length ratio to be multiplied by 1.81 and displacement-length ratio by 35.9.

11.5 Froude number is a factor of 0.298 times speed-length ratio. Since using SI units in dimensional speed-length ratio will change the values used, it is logical to use the dimensionless ratio, that is, the Froude number. Thus, Froude number should be used in place of speed-length ratio when designing in the SI system.

12. Conversion Factors

12.1 Table 6 and Table 7 provide conversion factors to SI for those quantities commonly used in the marine industry.

12.2 The maritime industry is subject to a complexity of national and international laws, treaties, regulations, and long term safety and contractual obligations which in some instances prevent unilateral changes from customary maritime language and usage of SI basic and supplementary terms. Therefore, Table 6 provides, in addition to the recommended SI units, a number of non-SI units permitted for use until such time as the preferred SI units can be adopted without detriment.

12.3 To convert a present unit to its equivalent SI unit or unit permitted for use, multiply the present unit in column 3 by the multiplication factor shown in column 6. To convert to present units, divide the SI unit by the factor.

12.4 Conversion factors are presented for ready adaptation to computer readout and electronic data transmission. The factors are written as a number equal to or greater than one and less than ten with six or fewer decimal places. This number is followed by the letter \(E\) (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

\[3.523 \times 10^{-2}\]

Similarly:

\[3.386 \times 10^{3}\]

13. Keywords

13.1 measurement; metric; metric for maritime applications

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### TABLE 6 Conversion Table

<table>
<thead>
<tr>
<th>ISO No.(^4)</th>
<th>Quantity/Areas of Use</th>
<th>Present Units</th>
<th>Preferred SI Units</th>
<th>Units Permitted for Use with SI(^6)</th>
<th>Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1.1</td>
<td>Plane angle:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Machine design</td>
<td>radian (rad)</td>
<td>radian (rad)</td>
<td></td>
<td>1.0(^C)</td>
</tr>
<tr>
<td></td>
<td>Angle of entrance of hull, engine timing, navigation(^5)</td>
<td>degree (°)</td>
<td>degree (°)</td>
<td>1 min = 1.666 667 E − 02(^*)</td>
<td>1.0(^C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>degree (°)</td>
<td>degree (°)</td>
<td></td>
<td>1 s = 2.777 778 E − 04(^*)</td>
</tr>
<tr>
<td>1-3.1</td>
<td>Length:</td>
<td>nautical mile(^5)</td>
<td>kilometre (km)</td>
<td>1 nautical mile = 1.852 km(^C)</td>
<td>1.0(^C)</td>
</tr>
<tr>
<td></td>
<td>Distances</td>
<td>statute mile</td>
<td>kilometre (km)</td>
<td>1 statute mile = 1.609 347 km</td>
<td>1.0(^C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>international mile</td>
<td>kilometre (km)</td>
<td>1 international mile = 1.609 344 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depth of water, length of cables, wires, and ropes</td>
<td>fathom(^5)</td>
<td>metre (m)</td>
<td>1 fathom = 1.828 804 E + 00 m</td>
<td></td>
</tr>
<tr>
<td>ISO No.</td>
<td>Area of Use</td>
<td>Present Units</td>
<td>Preferred SI Units</td>
<td>Units Permitted for Use with SI</td>
<td>Conversion Factors</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------</td>
<td>--------------------</td>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1-4.1</td>
<td>Deck heights, draft, main hull dimensions, stability data, location of centers of gravity, buoyancy and flotation, KM, KG, GM, and GZ</td>
<td>foot and inch</td>
<td>metre (m)</td>
<td></td>
<td>1 foot = 3.048 000 E - 01 m²</td>
</tr>
<tr>
<td>1-4.1a</td>
<td>First moment of area: Structure design, midship section</td>
<td>inch² foot</td>
<td>cubic metre (m³)</td>
<td></td>
<td>1 in.² ft = 1.966 448 E - 04 m³</td>
</tr>
<tr>
<td>1-4.1b</td>
<td>Section modulus: Frames and associated plating</td>
<td>inch³ foot</td>
<td>cubic millimetre (mm³)</td>
<td></td>
<td>1 in.³ = 1.638 706 E + 04 mm³</td>
</tr>
<tr>
<td>1-4.1c</td>
<td>Second moment of area: Structure design, midship section</td>
<td>inch² foot²</td>
<td>metre⁴(m⁴)</td>
<td></td>
<td>1 in.² ft² = 5.993 733 E - 05 m⁴</td>
</tr>
<tr>
<td>1-5.1</td>
<td>Volume: Freight volume measurement¹</td>
<td>ton of 40 ft³</td>
<td>cubic metre (m³)</td>
<td></td>
<td>1 freight ton = 1.132 674 E + 00 m³</td>
</tr>
<tr>
<td></td>
<td>Gross and net tonnage (measurement ton)</td>
<td>ton of 100 ft³</td>
<td>cubic metre (m³)</td>
<td></td>
<td>1 measurement ton = 2.831 685 E + 00 m³</td>
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<tr>
<td></td>
<td>Volume of displacement, volume of holds, large air receivers</td>
<td>cubic foot</td>
<td>cubic metre (m³)</td>
<td></td>
<td>1 ft³ = 2.831 685 E - 02 m³</td>
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<tr>
<td></td>
<td>Volume of large fuel tanks</td>
<td>barrel (42 gallons)</td>
<td>cubic metre (m³)</td>
<td></td>
<td>1 bbl = 1.589 873 E - 01 m³</td>
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<tr>
<td></td>
<td>Volume of small tanks and small air receivers</td>
<td>U.S. gallon (liquid)</td>
<td>cubic metre (m³)</td>
<td>1 gal = 3.785 412 E - 03 m³</td>
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<tr>
<td></td>
<td>Specific volume: Storage factors for solid and liquid cargo, fuel oil and water</td>
<td>foot³ per ton</td>
<td>cubic metre per kilogram (m³/kg)</td>
<td></td>
<td>1 ft³/ton = 2.786 963 E - 05 m³</td>
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<tr>
<td></td>
<td>Gases and vapors</td>
<td>foot³ per pound</td>
<td>cubic metre per kilogram (m³/kg)</td>
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<td>1 ft³/lb = 6.242 796 E - 02 m³</td>
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<td></td>
<td>Volume flow: Capacity of air compressors, fans, large pumps</td>
<td>foot³ per minute</td>
<td>cubic metre per second (m³/s)</td>
<td></td>
<td>1 ft³/min = 4.719 474 E - 04 m³</td>
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<td>Capacity of most pumps</td>
<td>gallon per minute</td>
<td>cubic metre per second (m³/s)</td>
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<td>1 gal/min = 6.309 020 E - 05 m³</td>
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<td></td>
<td>Barrel per day</td>
<td>barrel per day</td>
<td>cubic metre per second (m³/s)</td>
<td></td>
<td>1 bbl/d = 1.840 131 E - 06 m³</td>
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¹ Measurement ton
² freight ton
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<td>Angular velocity:</td>
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<td>Angular acceleration:</td>
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<td>Velocity:</td>
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<td>1-10.1</td>
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<td>2-3.1</td>
<td>Frequency:</td>
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<td>Rotational speed:</td>
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<td>Density:</td>
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**TABLE 6 Continued**

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<td>12</td>
<td>Density of liquids</td>
<td>pound per gallon</td>
<td>kilogram per cubic metre (kg/m²³)</td>
<td>kilogram per litre (kg/L)</td>
<td>1 lb/gal = 1.198 264 E+02 kg/m³</td>
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<tr>
<td>3-2.1a</td>
<td>Concentration: Salinity</td>
<td>pound per foot³</td>
<td>kilogram per cubic metre (kg/m³²)</td>
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<td>1 lb/ft³ = 1.601 846 E+01 kg/m³</td>
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<td>3-7.1</td>
<td>Momentum: Machine design</td>
<td>pound foot per second</td>
<td>kilogram metre per second (kg·m/s)</td>
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<td>1 lb·ft/s = 1.382 550 E−01 kg·m/s</td>
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<td>3-8.1</td>
<td>Moment of momentum: (Angular momentum) machine design</td>
<td>pound foot² per second</td>
<td>kilogram metre squared per second (kg·m²/s)</td>
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<td>1 lb·ft²/s = 4.214 011 E−02 kg·m²/s</td>
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<td>3-9.1</td>
<td>Moment of inertia: Machine design</td>
<td>pound foot²</td>
<td>kilogram metre² (kg·m²)</td>
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<td>1 lb·ft² = 2.926 397 E−04 kg·m²</td>
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<td>3-10.1</td>
<td>Force: Machine and structure design</td>
<td>ton-force</td>
<td>kilonewton (kN)</td>
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<td>1 tonf = 9.964 017 E+00 kN</td>
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<td>3-12.1</td>
<td>Moment of force (torque): Machine and structure design, bending moments</td>
<td>foot ton-force</td>
<td>kilonewton metre (kN·m)</td>
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<td>1 tonf·ft = 3.037 032 E+00 kN·m</td>
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<td>3-13.1</td>
<td>Pressure: Normal fluid pressure, (for example, compressed air, oil, steam)</td>
<td>pound-force per inch²</td>
<td>kilopascal (kPa) or MPa</td>
<td></td>
<td>1 lbf/in.² = 6.894 757 E+00 kPa</td>
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<td>Bearing pressures</td>
<td>kilogram-force per centimetre²</td>
<td>kilopascal (kPa) or MPa</td>
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<td>1 kgf/cm² = 9.806 650 E+01 kPa</td>
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<td>Barometric measurements and pressures of small magnitude</td>
<td>inch of mercury (60°F)</td>
<td>kilopascal (kPa)</td>
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<td>1 in. H₂O = 3.377 856 E+00 kPa</td>
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<td>Differential pressures</td>
<td>inch of water (60°F)</td>
<td>kilopascal (kPa)</td>
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<td>1 in. H₂O = 2.488 400 E−01 kPa</td>
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<td>Ventilation pressures</td>
<td>inch of water (ISO)</td>
<td>kilopascal (kPa)</td>
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<td>1 in. H₂O = 2.490 89 E−01 kPa</td>
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<td>3-13.2</td>
<td>Stress: Stresses in materials</td>
<td>pound-force per inch²</td>
<td>megapascal (MPa) or GPa</td>
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<td>1 lbf/in.² = 6.894 757 E−03 MPa</td>
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<tr>
<td></td>
<td>ton-force per inch²</td>
<td>megapascal (MPa) or GPa</td>
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<td>1 tonf/in.² = 1.535 495 E+04 MPa</td>
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<td></td>
<td>kip per inch²</td>
<td>megapascal (MPa) or GPa</td>
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<td>1 kip/in.² = 6.894 757 E+00 MPa</td>
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<td>3-21.1</td>
<td>Dynamic viscosity: Viscosity of liquids and gases</td>
<td>centipoise (cP)</td>
<td>millipascal second (mPa·s)</td>
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<td>1.0°C</td>
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<td></td>
<td>pound force second per square foot</td>
<td>pascal second (Pa·s)</td>
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<td>1 lbf·s/ft² = 4.788 026 E+01 Pa·s</td>
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<td>3-22.1</td>
<td>Kinematic viscosity: Viscosity of liquids</td>
<td>centistokes (cSt)</td>
<td>square millimetre per second (mm²/s)</td>
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<td></td>
<td>square foot per second</td>
<td>square metre per second (m²/s)</td>
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<td>1 ft²/s = 9.290 304 E−02 m²/s</td>
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<td>3-24.1</td>
<td>Energy, work: Thermodynamics</td>
<td>Btu</td>
<td>kilojoule (kJ) or any multiple joule (J) or any multiple</td>
<td></td>
<td>1 Btu = 1.055 056 E+00 kJ</td>
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<tr>
<td></td>
<td>foot pound-force</td>
<td>kilojoule (kJ) or any multiple joule (J) or any multiple</td>
<td></td>
<td>1 ft-lbf = 1.355 818 E+00 J</td>
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<tr>
<td></td>
<td>calorie (international)</td>
<td>joule (J) or any multiple joule (J) or any multiple</td>
<td></td>
<td>4.186 800 E+00 J</td>
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<td>3-25.1</td>
<td>Power:</td>
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<td>ISO No.</td>
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<td>1</td>
<td>Mechanical, electrical or hydraulic power of normal magnitude</td>
<td>horsepower (SHP, BHP, etc.)</td>
<td>kilowatt (kW)</td>
<td>1 hp = 7,457 000 E − 01 kW</td>
<td>1 hp = 7,457 000 E − 01 kW</td>
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<td>4-1.1</td>
<td>Absolute temperature: Thermodynamic calculations</td>
<td>foot pound force per second</td>
<td>watt (W)</td>
<td>1 ft-lb/s = 1.355 818 E + 00 W</td>
<td>1 ft-lb/s = 1.355 818 E + 00 W</td>
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<td>4-2.1</td>
<td>Temperature: All measured and specified degree Fahrenheit</td>
<td>degree Rankine</td>
<td>kelvin (K)</td>
<td>$T_R = T_F/1.8$</td>
<td>$T_R = T_F/1.8$</td>
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<td>4-2.1a</td>
<td>Temperature interval: All temperature intervals</td>
<td>degree Fahrenheit</td>
<td>degree Celsius (°C)</td>
<td>$t_F = (t_C + 32)/1.8$</td>
<td>$t_F = (t_C + 32)/1.8$</td>
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<td>4-3.1</td>
<td>Linear expansion coefficient: All linear expansion coefficients</td>
<td>inch per inch per degree Fahrenheit</td>
<td>metre per metre per kelvin (m/m) K $^{-1}$</td>
<td>$1°F = 5/9°C$</td>
<td>$1°F = 5/9°C$</td>
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<td>4-6.1</td>
<td>Heat, quantity of heat: Thermodynamics, refrigeration</td>
<td>Btu</td>
<td>joule (J) and its multiples</td>
<td>1 Btu = 1.055 056 E + 00 kJ</td>
<td>1 Btu = 1.055 056 E + 00 kJ</td>
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<td>4-7.1</td>
<td>Heat flow rate: Boiler and heat exchanger design</td>
<td>Btu per second</td>
<td>watt (W) and its multiples</td>
<td>1 Btu/s = 1.055 056 E + 00 W</td>
<td>1 Btu/s = 1.055 056 E + 00 W</td>
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<td>Density of heat flow rate: Boiler and heat exchanger design</td>
<td>Btu per foot$^2$ hour</td>
<td>watt per square metre (W/m$^2$)</td>
<td>1 Btu/(ft$^2$·h) = 3.154 591 E + 00 W/m$^2$</td>
<td>1 Btu/(ft$^2$·h) = 3.154 591 E + 00 W/m$^2$</td>
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<td>4-7.1b</td>
<td>Volumetric heat release rate: Boiler design</td>
<td>Btu per foot$^2$ hour</td>
<td>watt per cubic metre (W/m$^3$)</td>
<td>1 Btu/(ft$^3$·h) = 1.034 971 E + 01 W/m$^3$</td>
<td>1 Btu/(ft$^3$·h) = 1.034 971 E + 01 W/m$^3$</td>
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<tr>
<td>4-7.1c</td>
<td>Fuel consumption rate: Specific fuel consumption</td>
<td>pound per horsepower hour</td>
<td>kilogram per joule (kg/J)</td>
<td>1 lb/hph = 1.689 659 E − 07 kg/J</td>
<td>1 lb/hph = 1.689 659 E − 07 kg/J</td>
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<td>4-9.1</td>
<td>Thermal conductivity: Heat exchanger design</td>
<td>Btu inch per foot$^2$ hour</td>
<td>watt per metre °C (W/(m·°C)) or W/(m·K)</td>
<td>1 Btu·in/(ft$^2$·h·°F) = 1.442 279 E − 01 W/(m·°C)</td>
<td>1 Btu·in/(ft$^2$·h·°F) = 1.442 279 E − 01 W/(m·°C)</td>
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<td>4-10.1</td>
<td>Coefficient of heat transfer: Heat exchanger design</td>
<td>Btu per hour-foot$^2$ degree Fahrenheit</td>
<td>watt per square metre degree C (W/(m$^2$·°C)) or W/(m$^2$·K)</td>
<td>1 Btu/(ft$^2$·°F) = 5.678 263 E + 00 W/m$^2$·°C</td>
<td>1 Btu/(ft$^2$·°F) = 5.678 263 E + 00 W/m$^2$·°C</td>
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<td>Specific heat capacity: Thermodynamics, applied heat, refrigeration</td>
<td>Btu per pound degree F</td>
<td>kilojoule per kilogram kelvin (kJ/(kg·K))</td>
<td>1 Btu/(lb·°F) = 4.186 800 E + 00 kJ/(kg·K)</td>
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<td>Specific entropy: Thermodynamics</td>
<td>Btu per pound degree R</td>
<td>kilojoule per kilogram kelvin (kJ/kg·K)</td>
<td>1 Btu/(lb·°R) = 4.186 800 E + 00 kJ/kg·K</td>
<td>1 Btu/(lb·°R) = 4.186 800 E + 00 kJ/kg·K</td>
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<td>Specific internal energy: Calorific value, specific latent heat thermodynamics, refrigeration</td>
<td>Btu pound</td>
<td>kilojoule per kilogram (kJ/kg)</td>
<td>1 Btu/lb = 2.326 000 E + 00 kJ/kg</td>
<td>1 Btu/lb = 2.326 000 E + 00 kJ/kg</td>
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<td>Quantity of electricity: Electrical charge</td>
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<td>coulomb (C)</td>
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<td>5-6.3</td>
<td>Electromotive force, potential:</td>
<td>ampere hour (A·h)</td>
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<td>5-9.1</td>
<td>Capacitance</td>
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<td>5-17.1</td>
<td>Magnetic field intensity</td>
<td>oersted</td>
<td>ampere per metre (A/m)</td>
<td>1 oersted = 7.957 747 E + 01 A/m</td>
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<td>Magnetomotive force</td>
<td>gilbert</td>
<td>ampere (A)</td>
<td>1 gilbert = 7.957 747 E − 01 A</td>
<td>1 gilbert = 7.957 747 E − 01 A</td>
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<td>Magnetic flux density</td>
<td>tesla (T)</td>
<td>1 tesla = 1.000 000 E − 04 T</td>
<td>1 tesla = 1.000 000 E − 04 T</td>
<td>1 tesla = 1.000 000 E − 04 T</td>
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<td>5-20.1</td>
<td>Magnetic flux</td>
<td>weber (Wb)</td>
<td>1 weber = 1.000 000 E − 08 Wb</td>
<td>1 weber = 1.000 000 E − 08 Wb</td>
<td>1 weber = 1.000 000 E − 08 Wb</td>
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<td>5-22.1</td>
<td>Inductance</td>
<td>henry</td>
<td>henry (H)</td>
<td>1 henry = 1.000 000 E + 03 H</td>
<td>1 henry = 1.000 000 E + 03 H</td>
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<td>5-24.1</td>
<td>Permeability</td>
<td>gauss/oersted</td>
<td>henry per metre (H/m)</td>
<td>1 gauss/oersted = 1.257 E + 06 H/m</td>
<td>1 gauss/oersted = 1.257 E + 06 H/m</td>
</tr>
<tr>
<td>5-33.1</td>
<td>Resistance</td>
<td>ohm</td>
<td>ohm (Ω)</td>
<td>1 ohm = 1.000 000 E + 06 Ω</td>
<td>1 ohm = 1.000 000 E + 06 Ω</td>
</tr>
<tr>
<td>5-34.1</td>
<td>Conductance</td>
<td>siemens (S)</td>
<td>1 siemens = 1.000 000 E − 06 S</td>
<td>1 siemens = 1.000 000 E − 06 S</td>
<td>1 siemens = 1.000 000 E − 06 S</td>
</tr>
</tbody>
</table>
### TABLE 6  Continued

<table>
<thead>
<tr>
<th>ISO No.</th>
<th>Quantity/Area of Use</th>
<th>Present Units</th>
<th>Preferred SI Units</th>
<th>Units Permitted for Use with SI</th>
<th>Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-35.1</td>
<td>Resistivity</td>
<td>ohm-centimetre (Ω·cm)</td>
<td>ohm-metre (Ω·m)</td>
<td>1 Ω·cm = 1.000 000 E − 02 Ω·m</td>
<td>1.0E−02</td>
</tr>
<tr>
<td>5-36.1</td>
<td>Conductivity</td>
<td>ohm circular-mil per foot (Ω·mil·ft)</td>
<td>ohm millimetre² per metre (Ω·mm²/m)</td>
<td>1 Ω·mil·ft = 1.662 426 E − 03 Ω·mm²/m</td>
<td>1.0E−03</td>
</tr>
<tr>
<td>5-44.1</td>
<td>Electric power</td>
<td>mho per centimetre</td>
<td>siemens per metre (S/m)</td>
<td>1 mho/cm = 1.000 000 E + 02 S/m</td>
<td>1.0E02</td>
</tr>
</tbody>
</table>

C Indicates exact conversion value.

D Minutes and seconds of plane angle may still be used for navigation purposes.

E For values of nautical mile and knot, see Table 6.

H All tonnage measurements are long tons (2240 pounds). The short ton (2000 pounds) equals 0.907 185 t.

### TABLE 7  Alphabetical List of Units

<table>
<thead>
<tr>
<th>Present Units</th>
<th>Preferred SI Units</th>
<th>Units Permitted for Use with SI</th>
<th>Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>ampere</td>
<td>ampere (A)</td>
<td>1.0A</td>
<td></td>
</tr>
<tr>
<td>ampere hour</td>
<td>ampere hour (A·h)</td>
<td>1 A·h = 3.6 E + 3 C^4</td>
<td></td>
</tr>
<tr>
<td>barrel (42 gal)</td>
<td>cubic metre (m^3)</td>
<td>1 bbl = 1.589 873 E − 01 m^3</td>
<td></td>
</tr>
<tr>
<td>barrel/day</td>
<td>cubic metre per second (m^3/s)</td>
<td>1 bbl/d = 1.840 131 E − 05 m^3/s</td>
<td></td>
</tr>
<tr>
<td>barrel/ton</td>
<td>cubic metre per metric (m^3/m)</td>
<td>1 bbl/ton = 1.589 873 E − 01 m^3/m</td>
<td></td>
</tr>
<tr>
<td>Btu</td>
<td>joule (J)</td>
<td>1 Btu = 1.055 056 E + 00 J</td>
<td></td>
</tr>
<tr>
<td>Btu per foot²</td>
<td>watt per square metre (W/m²)</td>
<td>1 Btu/(ft²·h) = 3.154 59 E + 00 W/m²</td>
<td></td>
</tr>
<tr>
<td>Btu per second</td>
<td>watt (W)</td>
<td>1 Btu/s = 1.034 971 E + 01 W</td>
<td></td>
</tr>
<tr>
<td>Btu per hour</td>
<td>watt (W)</td>
<td>1 Btu/h = 2.930 711 E − 01 W</td>
<td></td>
</tr>
<tr>
<td>Btu per foot²</td>
<td>watt per square metre degree C (W/m²°C)</td>
<td>1 Btu/(ft²·°F) = 5.678 263 E + 00 W/m²·°F</td>
<td></td>
</tr>
<tr>
<td>Btu inch per foot²</td>
<td>watt per square metre °F (W/m²·°F)</td>
<td>1 Btu/in²·°F·h = 1.442 279 E − 01 W/m²·°C</td>
<td></td>
</tr>
<tr>
<td>Btu per pound</td>
<td>kilojoule per kilogram (kJ/kg)</td>
<td>1 Btu/lb = 2.326 000 E + 00 kJ/kg</td>
<td></td>
</tr>
<tr>
<td>Btu per pound</td>
<td>kilojoule per (kilogram kelvin) (kJ/kg·K)</td>
<td>1 Btu/lb·°F = 4.186 800 E + 00 kJ/kg·°F</td>
<td></td>
</tr>
<tr>
<td>calorific (international)</td>
<td>joule (J)</td>
<td>1 Btu/s = 1.055 056 E + 00 W</td>
<td></td>
</tr>
<tr>
<td>candlepower, candle</td>
<td>candela (cd)</td>
<td>1 candlepower = 1 cd</td>
<td></td>
</tr>
<tr>
<td>centipoise (cP)</td>
<td>square millimetre per second (mm²/s)</td>
<td>1 cP = 1.0E−06</td>
<td></td>
</tr>
<tr>
<td>centistokes (cSt)</td>
<td>millipascal second (mPa·s)</td>
<td>1 cSt = 1.0E−04</td>
<td></td>
</tr>
<tr>
<td>cycle/second</td>
<td>hertz (Hz)</td>
<td>1 Hz = 1.0E01 Hz</td>
<td></td>
</tr>
</tbody>
</table>

A ISO number is from ISO 31 classification system.

B Units permitted for use with SI are in common use throughout the international maritime industry. The switch to preferred SI units should be made as conditions permit.

C Indicates exact conversion value.

D Minutes and seconds of plane angle may still be used for navigation purposes.

E For values of nautical mile and knot, see Table 6.

F Conversion based on the foot and one fathom equal to six feet.

G The volume measurement for those not using the metric system is generally 40 cubic feet, however, 50 cubic feet is used occasionally. It is recommended that the cubic metre (35.315 cubic feet) be used as the replacement unit. The conversion factor of one non-metric measurement ton (40 cubic feet) equals 1.132 67 cubic metres. One cubic metre of 35.315 cubic feet equals 0.883 non-metric measurement tons. The conversion of tariffs filed with the Federal Maritime Commission must be accomplished in accordance with their filing requirements.

H All tonnage measurements are long tons (2240 pounds). The short ton (2000 pounds) equals 0.907 185 t.

I An apparent anomaly exists in the case of the joule for work (J = N·m) and the use of N·m for torque or bending moment. These are, however, entirely different units. In the former, the unit of work results from unit force moving through unit distance. In the latter unit force acts at right angles to the lever arm of unit length. The distinction would be readily seen if vectors were incorporated in the unit symbols. For these reasons, it is important to express work or energy in joules and moment of force or torque in newton metres, not joules. The use of newton metre per radian as the unit of torque in rotational dynamics will result in dimensional integrity.

J It has been internationally recommended that pressure units themselves should not be modified to indicate whether pressure is “absolute” (that is above zero) or “gage” (that is, above atmospheric pressure). If, therefore, the context leaves any doubt as to which is meant, the word “pressure” must be qualified appropriately. (For example, “. . . at a gage pressure of 13 kPa” or “. . . at an absolute pressure of 13 kPa” or “. . . reached an absolute pressure of 13 kPa.”)
<table>
<thead>
<tr>
<th>Present Units</th>
<th>Preferred SI Units</th>
<th>Units Permitted for Use with SI</th>
<th>Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>degree Fahrenheit</td>
<td>degree Celsius (°C) or kelvin (K)</td>
<td></td>
<td>$1°F = 5/9°C^a$</td>
</tr>
<tr>
<td>degree Rankine</td>
<td>kelvin (K)</td>
<td>$T_k = T_r/1.8$</td>
<td>$1°F = 5/9 K^a$</td>
</tr>
<tr>
<td>farad</td>
<td>farad (F)</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>fathom</td>
<td>metre (m)</td>
<td></td>
<td>1 fathom = 1.828 804 E + 00 m</td>
</tr>
<tr>
<td>foot</td>
<td>metre (m)</td>
<td></td>
<td>1 foot = 3.048 000 E - 01 m^a</td>
</tr>
<tr>
<td>foot</td>
<td>millimetre (mm)</td>
<td></td>
<td>1 foot = 3.048 000 E + 02 mm^m</td>
</tr>
<tr>
<td>foot</td>
<td>decimetre (dm)</td>
<td></td>
<td>1 foot = 3.048 000 E + 00 dm^d</td>
</tr>
<tr>
<td>foot^2</td>
<td>square metre (m^2)</td>
<td></td>
<td>1 ft^2 = 9.290 304 E - 02 m^2</td>
</tr>
<tr>
<td>foot^3</td>
<td>cubic metre (m^3)</td>
<td></td>
<td>1 ft^3 = 2.831 685 E - 02 m^3</td>
</tr>
<tr>
<td>footcandle</td>
<td>lux (lx)</td>
<td></td>
<td>1 footcandle = 1.076 391 E + 01 lx</td>
</tr>
<tr>
<td>foot pound-force</td>
<td>joule (J) or any multiple</td>
<td></td>
<td>1 ft·lbf = 1.355 818 E + 00 J</td>
</tr>
<tr>
<td>foot pound force per second</td>
<td>watt (W)</td>
<td></td>
<td>1 ft·lbf/s = 1.355 818 E + 00 W</td>
</tr>
<tr>
<td>foot^2/pound</td>
<td>cubic metre per second (m^3/s)</td>
<td></td>
<td>1 ft^2/lb = 6.242 796 E - 02 m^3/kg</td>
</tr>
<tr>
<td>foot^2/ton</td>
<td>cubic metre per kilogram (m^3/kg)</td>
<td></td>
<td>1 ft^2/ton = 6.242 796 E - 02 m^3/kg</td>
</tr>
<tr>
<td>foot^2/ton</td>
<td>cubic metre per metric ton (m^3/t)</td>
<td></td>
<td>1 ft^2/ton = 6.242 796 E - 02 m^3/kg</td>
</tr>
<tr>
<td>foot^3/pound</td>
<td>litre per second (L/s)</td>
<td></td>
<td>1 ft^3/lb = 6.242 796 E - 02 m^3/kg</td>
</tr>
<tr>
<td>foot^3/ton</td>
<td>cubic metre per metric ton (m^3/t)</td>
<td></td>
<td>1 ft^3/ton = 2.786 963 E + 05 m^2/kg</td>
</tr>
<tr>
<td>foot^3/pound</td>
<td>litre per kilogram (L/kg)</td>
<td></td>
<td>1 ft^3/lb = 6.242 796 E - 02 m^3/kg</td>
</tr>
<tr>
<td>foot pound-force (torque)</td>
<td>newton metre (N·m)</td>
<td></td>
<td>1 ft·lbf = 1.355 818 E + 00 J</td>
</tr>
<tr>
<td>foot pound-force (energy)</td>
<td>joule (J)</td>
<td></td>
<td>1 ft·lbf = 1.355 818 E + 00 J</td>
</tr>
<tr>
<td>foot poundal</td>
<td>newton metre (N·m)</td>
<td></td>
<td>1 ft·lbf = 1.355 818 E + 00 J</td>
</tr>
<tr>
<td>foot/second</td>
<td>metre per second (m/s)</td>
<td></td>
<td>1 ft/s = 3.048 000 E - 01 m/s</td>
</tr>
<tr>
<td>foot/second^2</td>
<td>metre per second squared (m/s^2)</td>
<td></td>
<td>1 ft/s^2 = 3.048 000 E + 02 m/s^2</td>
</tr>
<tr>
<td>foot ton-force</td>
<td>kilowatt metre (kW·m)</td>
<td></td>
<td>1 tonf·ft = 1.337 030 E + 00 kN·m</td>
</tr>
<tr>
<td>gallon U.S. (liquid)</td>
<td>cubic metre (m^3)</td>
<td></td>
<td>1 gal = 3.785 412 E - 03 m^3</td>
</tr>
<tr>
<td>gallon U.S. (liquid)</td>
<td>litre (L)</td>
<td></td>
<td>1 gal = 3.785 412 E - 03 L</td>
</tr>
<tr>
<td>gallon/minute</td>
<td>cubic metre per second (m^3/s)</td>
<td></td>
<td>1 gal/min = 6.309 042 E - 03 m^3/s</td>
</tr>
<tr>
<td>gallon/minute</td>
<td>litre per second (L/s)</td>
<td></td>
<td>1 gal/min = 6.309 042 E - 03 L/s</td>
</tr>
<tr>
<td>gauss</td>
<td>tesla (T)</td>
<td></td>
<td>1 gauss = 1.000 000 E - 04 T</td>
</tr>
<tr>
<td>gauss/oersted</td>
<td>henry per metre (H/m)</td>
<td></td>
<td>1 gauss/oersted = 1.257 664 E - 06 H/m</td>
</tr>
<tr>
<td>grains per gallon</td>
<td>kilogram per cubic metre (kg/m^3)</td>
<td></td>
<td>1 grain/gal = 1.711 870 E - 02 kg/m^3</td>
</tr>
<tr>
<td>grains per gallon</td>
<td>grams per litre (g/L)</td>
<td></td>
<td>1 grain/gal = 1.711 870 E - 02 g/L</td>
</tr>
<tr>
<td>henry</td>
<td>henry (H)</td>
<td></td>
<td>1 henry = 1.000 000 E + 00 H</td>
</tr>
<tr>
<td>horsepower (SHP, BHP, etc.)</td>
<td>kilowatt (kW)</td>
<td></td>
<td>1 hp = 7.457 000 E + 00 kW</td>
</tr>
<tr>
<td>hundred weight (cwt)</td>
<td>kilogram (kg)</td>
<td></td>
<td>1 cwt = 5.080 235 E + 00 kg</td>
</tr>
<tr>
<td>inch</td>
<td>millimetre (mm)</td>
<td></td>
<td>1 in. = 2.540 000 E + 00 mm</td>
</tr>
<tr>
<td>inch^2</td>
<td>square millimetre (mm^2)</td>
<td></td>
<td>1 in.^2 = 6.451 600 E + 00 mm^2</td>
</tr>
<tr>
<td>inch^3</td>
<td>millimetre cubed (mm^3)</td>
<td></td>
<td>1 in.^3 = 1.638 706 E + 00 mm^3</td>
</tr>
<tr>
<td>inch^4</td>
<td>millimetre^4 (mm^4)</td>
<td></td>
<td>1 in.^4 = 4.162 314 E + 05 mm^4</td>
</tr>
<tr>
<td>inch^2 foot</td>
<td>cubic metre (m^3)</td>
<td></td>
<td>1 in.^2 ft = 1.966 448 E + 00 m^3</td>
</tr>
<tr>
<td>inch^3 foot^2</td>
<td>metre centimetre^2 (m·cm^2)</td>
<td></td>
<td>1 in.^3 ft^2 = 1.966 448 E + 00 m·cm^2</td>
</tr>
<tr>
<td>inch^3 foot^3</td>
<td>metre^3 (m^3)</td>
<td></td>
<td>1 in.^3 ft^3 = 1.966 448 E + 00 m^3</td>
</tr>
<tr>
<td>inch^2 foot^2</td>
<td>metre^2 (m^2)</td>
<td></td>
<td>1 in.^2 ft^2 = 5.993 733 E + 03 m^2</td>
</tr>
<tr>
<td>inch per inch °F</td>
<td>metre per metre-kelvin (K^-1)</td>
<td></td>
<td>1 in./in. ° F = 1 + 00 mm · km</td>
</tr>
<tr>
<td>inch of water (60°F)</td>
<td>kilopascal (kPa)</td>
<td></td>
<td>1 in. H_2O = 2.488 400 E - 01 kPa</td>
</tr>
<tr>
<td>inch of water (ISO conv.)</td>
<td>kilopascal (kPa)</td>
<td></td>
<td>1 in. H_2O = 2.490 898 E - 01 kPa</td>
</tr>
<tr>
<td>inch of mercury (60°F)</td>
<td>kilopascal (kPa)</td>
<td></td>
<td>1 in. Hg = 3.376 850 E + 00 kPa</td>
</tr>
<tr>
<td>inch of mercury (ISO conv.)</td>
<td>kilopascal (kPa)</td>
<td></td>
<td>1 in. Hg = 3.376 850 E + 00 kPa</td>
</tr>
<tr>
<td>inch pound-force</td>
<td>newton metre (N·m)</td>
<td></td>
<td>1 lb·in. = 1.000 000 E - 04 N·m</td>
</tr>
<tr>
<td>kilogram-force per centimetre</td>
<td>kilopascal (kPa) or MPa</td>
<td></td>
<td>1 kgf/cm^2 = 9.806 650 E + 01 kPa</td>
</tr>
<tr>
<td>kip per inch</td>
<td>megapascal (MPa) or GPa</td>
<td></td>
<td>1kip/in. = 6.894 757 E + 00 MPa</td>
</tr>
<tr>
<td>knot</td>
<td>metre per second (m/s)</td>
<td></td>
<td>1 knot = 5.144 444 E + 01 m/s</td>
</tr>
<tr>
<td>lambert</td>
<td>candela per metre^2 (cd/m^2)</td>
<td></td>
<td>1 lambert = 3.183 099 E + 03 cd/m^2</td>
</tr>
<tr>
<td>lumen</td>
<td>lumen (lm)</td>
<td></td>
<td>1 lumen = 1.000 000 E + 00 W</td>
</tr>
<tr>
<td>maxwell</td>
<td>weber (Wb)</td>
<td></td>
<td>1 maxwell = 1.000 000 E - 08 Wb</td>
</tr>
<tr>
<td>mho</td>
<td>siemens (S)</td>
<td></td>
<td>1 mho = 1.000 000 E + 00 S/m^a</td>
</tr>
<tr>
<td>mho/centimetre</td>
<td>siemens per metre (S/m)</td>
<td></td>
<td>1 mho/cm = 1.000 000 E - 02 S/m^a</td>
</tr>
<tr>
<td>mil (10^-3 inch)</td>
<td>micrometre (µm)</td>
<td></td>
<td>1 mil = 2.540 000 E + 01 µm^a</td>
</tr>
<tr>
<td>mile (international)</td>
<td>kilometre (km)</td>
<td></td>
<td>1 international mile = 1.609 344 km</td>
</tr>
<tr>
<td>mile (nautical)</td>
<td>kilometre (km)</td>
<td></td>
<td>1 nautical mile = 1.852 km</td>
</tr>
<tr>
<td>mile (statute)</td>
<td>kilometre (km)</td>
<td></td>
<td>1 statute mile = 1.609 344 km</td>
</tr>
<tr>
<td>minute</td>
<td>degree (°)</td>
<td></td>
<td>1 min = 1.666 666 E - 02 deg</td>
</tr>
<tr>
<td>ohm</td>
<td>(Ω)</td>
<td></td>
<td>1 ohm = 1.000 000 E + 00 Ω</td>
</tr>
<tr>
<td>ohm-centimetre (Ω·cm)</td>
<td>ohm-centimetre (Ω·cm)</td>
<td></td>
<td>1 Ω·cm = 1.000 000 E - 02 Ω·m^a</td>
</tr>
<tr>
<td>ohm-circular-mil/foot</td>
<td>ohm-millimetre^2 per metre (Ω·mm^2/m)</td>
<td></td>
<td>1 Ω·cmmft = 1.662 426 E + 03 Ω·mm^2/m</td>
</tr>
<tr>
<td>ohm-oersted</td>
<td>ampere per metre (A/m)</td>
<td></td>
<td>1 oersted = 1.260 450 E + 00 A/m</td>
</tr>
<tr>
<td>pound</td>
<td>kilogram (kg)</td>
<td></td>
<td>1 lb = 0.453 592 E + 01 kg</td>
</tr>
<tr>
<td>pound foot</td>
<td>kilogram metre (kg·m)</td>
<td></td>
<td>1 lb·ft = 1.382 549 E - 01 kg·m</td>
</tr>
<tr>
<td>pound foot^2</td>
<td>kilogram metre^2 (kg·m^2)</td>
<td></td>
<td>1 lb·ft^2 = 2.414 110 E - 02 kg·m^2</td>
</tr>
<tr>
<td>pound foot per second</td>
<td>kilogram metre per second (kg·m/s)</td>
<td></td>
<td>1 lb·ft/s = 1.382 550 E - 01 kg·m/s</td>
</tr>
<tr>
<td>Present Units</td>
<td>Preferred SI Units</td>
<td>Units Permitted for Use with SI</td>
<td>Conversion Factors</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------</td>
<td>--------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>pound foot per second</td>
<td>kilogram metre squared per second</td>
<td></td>
<td>1 lb·ft²/s = 4.214 011 E − 02 kg·m²/s</td>
</tr>
<tr>
<td>pound-force</td>
<td>newton (N)</td>
<td>1 lbf = 4.448 222 E + 00 N</td>
<td></td>
</tr>
<tr>
<td>pound force per square foot</td>
<td>pascal second (Pa·s)</td>
<td>1 lbf/s·ft² = 4.788 026 E + 01 Pa·s</td>
<td></td>
</tr>
<tr>
<td>pound-force per inch²</td>
<td>megapascal (MPa) or GPa</td>
<td></td>
<td>1 lbf/in.² = 6.894 757 E − 03 MPa</td>
</tr>
<tr>
<td>pound inch²</td>
<td>kilogram metre (kg·m²)</td>
<td></td>
<td>1 lbf/in² = 6.894 757 E + 00 kPa</td>
</tr>
<tr>
<td>pound per foot²</td>
<td>kilogram per cubic metre (kg/m³)</td>
<td></td>
<td>1 lbf/ft³ = 1.601 846 E + 01 kg/m³</td>
</tr>
<tr>
<td>pound per gallon</td>
<td>kilogram per cubic metre (kg/m³)</td>
<td></td>
<td>1 lb/gal = 1.198 264 E + 02 kg/gal</td>
</tr>
<tr>
<td>pound per horsepower hour</td>
<td>kilogram per joule (kg/J)</td>
<td>kilogram per litre (kg/l)</td>
<td>1 lb/hp = 1.689 659 E − 07 kg/J</td>
</tr>
<tr>
<td>pound per hour</td>
<td>kilogram per second (kg/s)</td>
<td></td>
<td>1 lb/h = 1.259 979 E − 04 kg/s</td>
</tr>
<tr>
<td>pound per hour</td>
<td>kilogram per hour (kg/h)</td>
<td></td>
<td>1 lb/h = 4.535 924 E − 01 kg/h</td>
</tr>
<tr>
<td>pound per inch³</td>
<td>kilogram per cubic metre (kg/m³)</td>
<td></td>
<td>1 lb/in³ = 2.767 991 E + 04 kg/m³</td>
</tr>
<tr>
<td>pound per inch³</td>
<td>kilogram per cubic centimetre (kg/cm³)</td>
<td></td>
<td>1 lb/in³ = 2.767 991 E − 02 kg/cm³</td>
</tr>
<tr>
<td>rad (rd)</td>
<td>gray (Gy)</td>
<td></td>
<td>1 rad = 1.000 000 E − 02 Gy</td>
</tr>
<tr>
<td>radian/second</td>
<td>radian per second (rad/s)</td>
<td></td>
<td>1.0⁵</td>
</tr>
<tr>
<td>radian/second²</td>
<td>radian per second squared (rad/s²)</td>
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<tr>
<td>rem</td>
<td>sievert (Sv)</td>
<td></td>
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</tr>
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<td>revolutions per minute (r/min)</td>
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<td></td>
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<tr>
<td>roentgen (R)</td>
<td>coulomb/kilogram (C/kg)</td>
<td>R = 2.580 000 E − 04 C/kg⁴</td>
<td></td>
</tr>
<tr>
<td>second</td>
<td></td>
<td>1 s = 2.777 778 E − 04 deg</td>
<td></td>
</tr>
<tr>
<td>square foot per second</td>
<td>square metre per second (m²/s²)</td>
<td>1 ft²/s² = 9.290 304 E − 02 m²/s²⁴</td>
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<tr>
<td>ton (long)³</td>
<td>megagram (Mg)</td>
<td>1 ton = 1.016 047 E + 00 Mg</td>
<td></td>
</tr>
<tr>
<td>ton (long)</td>
<td>metric ton (t)</td>
<td>1 ton = 1.016 047 E + 00 t</td>
<td></td>
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<tr>
<td>ton of 40 ft³</td>
<td>cubic metre (m³)</td>
<td>1 freight ton = 1.132 674 E + 00 m³</td>
<td></td>
</tr>
<tr>
<td>ton of 100 ft³</td>
<td>cubic metre (m³)</td>
<td>1 measurement ton = 2.831 685 E + 00 m³</td>
<td></td>
</tr>
<tr>
<td>ton of refrigeration</td>
<td>kilowatt (kW)</td>
<td>1 ton (refrigeration) = 3.516 853 E + 00 kW</td>
<td></td>
</tr>
<tr>
<td>ton foot</td>
<td>megagram metre (Mg·m)</td>
<td></td>
<td>1 ton foot = 3.096 911 E − 01 Mg·m</td>
</tr>
<tr>
<td>ton foot per inch</td>
<td>kilogram metre per metre (kg·m/m)</td>
<td></td>
<td>1 ton·ft/m = 3.096 911 E − 01 t·m</td>
</tr>
<tr>
<td>ton foot per inch</td>
<td>metric ton metre per metre (t·m/m)</td>
<td></td>
<td>1 ton·ft/m = 1.219 256 E + 00 kg·m/m</td>
</tr>
<tr>
<td>ton foot per inch</td>
<td></td>
<td>1 ton·ft/m = 1.219 256 E + 00 t/m</td>
<td></td>
</tr>
<tr>
<td>ton foot per degree</td>
<td>kilogram metre per radian (kg·m/rad)</td>
<td>1 ton·ft/deg = 1.774 400 E + 00 kg·m/rad</td>
<td>1 ton·ft/deg = 3.096 911 E + 00 t/m/deg</td>
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<tr>
<td>ton foot per degree</td>
<td>ton metre per degree (t/m/degree)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ton-force</td>
<td>kilonewton (kN)</td>
<td>1 tonf = 9.964 017 E + 00 kN</td>
<td></td>
</tr>
<tr>
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<td>megagram per second (Mg/s)</td>
<td>1 ton/h = 2.822 352 E − 04 Mg/s</td>
<td></td>
</tr>
<tr>
<td>ton per hour</td>
<td>metric ton per hour (t/h)</td>
<td>1 ton/h = 1.016 047 E + 00 t/h</td>
<td></td>
</tr>
<tr>
<td>ton per inch</td>
<td>kilogram per metre (kg/m)</td>
<td>1 ton/in. = 4.000 185 E + 04 kg/m</td>
<td></td>
</tr>
<tr>
<td>ton per inch</td>
<td>metric ton per metre (t/m)</td>
<td>1 ton/in. = 4.000 185 E + 04 t/m</td>
<td></td>
</tr>
<tr>
<td>ton-force per inch²</td>
<td>megapascal (MPa) or GPa</td>
<td>1 tonf/in.² = 1.535 495 E − 04 MPa</td>
<td></td>
</tr>
<tr>
<td>volt</td>
<td>volt (V)</td>
<td>1.0⁶</td>
<td></td>
</tr>
<tr>
<td>watt</td>
<td>watt (W)</td>
<td>1.0⁴</td>
<td></td>
</tr>
<tr>
<td>yard²</td>
<td>square metre (m²)</td>
<td>1 yd² = 8.361 274 E − 01 m²</td>
<td></td>
</tr>
</tbody>
</table>

²Indicates exact conversion value.
³Unless otherwise noted, all tons are long tons (2240 lbs).
1. Scope

1.1 This specification provides design and construction criteria for double and single fire and foam station cabinets. See Fig. 1 and Fig. 2. Valves, hose, and fittings are not included.

1.2 Optional back and legs may be provided.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A 36M Specification for Structural Steel
A 53 Specification for Pipe, Steel, Black and Hot Dipped, Zinc Coated Welded and Seamless
A 167 Specification for Stainless and Heat-Resisting Chromium Nickel Steel Plate, Sheet and Strip
A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipe
A 569/A 569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip, Commercial Quality
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes and Tubes
F 593 Specification for Stainless Steel Bolts, Hex Cap Screws and Studs
F 594 Specification for Stainless Steel Nuts
F 783 Specification for Staple, Handgrab, Handle, and Stirrup Rung

2.2 American National Standards:
ANSI B18.21.1 Lock Washer

2.3 Other Standards:
American Bureau of Shipping Rules for Building and Classing of Steel Vessels
American Welding Society Publication, AWS D 1.1 Structural Welding Code

3. Classification

3.1 Type I, Single Cabinet (see Fig. 1 and Figs. 3-9):
3.1.1 Grade I—Right-hand door active leaf.
3.1.1.1 Class A, Mild Steel—Specification A 36/A 36M.
3.1.1.2 Class B, Stainless Steel—Specification A 167.
3.1.1.3 Class C, Aluminum—Specification B 209.
3.1.2 Grade 2—Left-hand door.
3.1.2.1 Class A, Mild Steel—Specification A 36/A 36M.
3.1.2.2 Class B, Stainless Steel—Specification A 167.
3.1.2.3 Class C, Aluminum—Specification B 209.

3.2 Type II, Double Cabinet (see Fig. 2 and Fig. 8):
3.2.1 Grade 1—Right-hand doors active leaf.
3.2.1.1 Class A, Mild Steel—Specification A 36/A 36M.
3.2.1.2 Class B, Stainless Steel—Specification A 167.
3.2.1.3 Class C, Aluminum—Specification B 209.

4. Ordering Information
4.1 Fire and foam cabinets ordered in accordance with this specification shall include the following:
4.1.1 ASTM title, designation, and year of issue,
4.1.2 Quantity (number of cabinets),
4.1.3 Type, grade, and class, and
4.1.4 Optional features.

5. Materials and Manufacture
5.1 Materials:
5.1.1 See Table 1.
5.1.2 Class materials.
5.1.2.1 All materials for Class A cabinets shall meet the requirements of Specifications A 53 and A 36/A 36M or Specification A 569/A 569M, except as specified in Table 1.
5.1.2.2 All materials for Class B cabinets shall meet the requirements of Specifications A 167 and A 312/A 312M, except as specified in Table 1.
5.1.2.3 All materials for Class C cabinets shall meet the requirements of Specifications B 209 and B 221 except as specified in Table 1.

5.2 Manufacture:
5.2.1 Welding shall be in accordance with the American Bureau of Shipping Rules for Building and Classing of Vessels or American Welding Society Structural Welding Code AWS D1.1.
5.2.2 Punchout shall have a 3-in. (approximately 76-mm) diameter hole with three evenly spaced 1⁄16-in. (approximately 1.5-mm) tabs for both sides of cabinet (see Fig. 3).

6. Workmanship, Finish, and Appearance
6.1 Fire and foam cabinets shall be free of weld spatter, burrs, and sharp corners, rough edges, and other defects which might be hazardous to personnel and equipment.
6.2 Surface Requirements:
6.2.1 Class A Cabinets—Coat with 1.0-mil dry film thickness, inorganic zinc silicate, including options.
6.2.2 Class B Cabinets—Uncoated. Optional legs coated with 1.0-mil dry film thickness, inorganic zinc silicate.
6.2.3 Class C Cabinets—Uncoated.

7. Packaging and Package Marking
7.1 Loose fasteners and hardware shall be packaged and securely attached inside each cabinet.
7.2 Shipping—Each cabinet shall bear a weathertight tag showing the purchase order number, ASTM standard designation, type, and name of manufacturer.
7.3 The cabinets shall be crated or attached to a pallet in a manner acceptable for shipment by commercial carrier. The cabinets shall be crated individually.

8. Keywords

8.1 fire; foam; foam station cabinet; marine technology; ships
FIG. 7 Hook Assembly Detail "C"

FIG. 8 Hose Rack Detail "D"
FIG. 9 Front View of Back Leg and Back Option Detail “E”
Standard Practice for
Human Engineering Program Requirements for Ships and
Marine Systems, Equipment, and Facilities

This standard is issued under the fixed designation F 1337; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice establishes and defines the requirements for
applying human engineering to the development and
acquisition of ships and marine systems, equipment, and
facilities. These requirements are applicable to all phases of
development, acquisition, and testing and shall be integrated
with the total system engineering and development, and test
effort. It is not expected nor intended that all of the human
engineering activities should be applied to every marine
program or program phase. Therefore, these activities shall be
tailored to meet the specific needs of each program and the
milestone phase of the program within the overall life cycle.
This tailoring shall be performed by the procuring activity or
by the contractor or subcontractor with the assistance and
approval of the procuring activity in order to impose only the
essential human engineering requirements on each program.
Guidance for selection of only the essential requirements is
contained in Appendix X1.

2. Referenced Documents

2.1 ASTM Standards:
F 1166 Practice for Human Engineering Design for Marine
Systems, Equipment and Facilities

2.2 Other Standard:
SNAME Sample Model Specification for Human Engineer-
ing Purposes—Technical and Research Bulletin 4–22

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 arrangement drawings—engineering design drawings
that provide plan, sectional, and elevation views of: (1) the
configuration and arrangement of major items of equipment
for manned compartments, spaces, or individual work stations, and
(2) within the work station, such as in a modular rack or on a
fiddleboard.

3.1.2 critical activity—any human activity that if not ac-

3.1.3 cultural expectation—the cause and effect relation-
ships (for example, red means stop or danger) that humans
learn from their culture.

3.1.4 duty—a set of operationally related tasks within a
given job (for example, communicating, operator mainte-
nance).

3.1.5 function—an activity performed by a system (for
example, provide electric power) to meet mission objectives.

3.1.6 human engineering—a specialized engineering disci-
pline within the area of human factors that applies scientific
knowledge of human physiological and psychological capabili-
ties and limitations to the design of hardware to achieve
effective man-machine integration.

3.1.7 human factors—the application of scientific knowl-
edge about human characteristics, covering both biomedical
and psychosocial considerations, to complete systems, indi-
vidual equipments, software, and facilities. This application is
through such specialized fields as human engineering, man-
ning, personnel selection, training, training devices and simu-
lation, life support, safety, job performance aids, and human
performance testing and evaluation.

3.1.8 human interface—any direct contact (that is, physical,
visual, or auditory) with a piece of hardware or software by a
human operator or maintainer.

3.1.9 job—the combination of all human performance re-
quired for operation and maintenance of one personnel position
in a system.

3.1.10 life support—that area of human factors that applies
scientific knowledge regarding the effects of environmental
factors on human behavior and performance to items that
require special attention or provisions for health promotion,
biomedical aspects of safety, protection, sustenance, escape,
survival, and recovery of personnel.

3.1.11 mission—a specific performance requirement im-
posed on one or more systems (for example, unload cargo)
within the operational requirements.

1 This practice is under the jurisdiction of ASTM Committee F25 on Ships and
Marine Technology and is the direct responsibility of Subcommittee F25.07 on
General Requirements.


3 Available from Society of Naval Architects and Marine Engineers, 601 Pavonia
Ave., Jersey City, NJ 07306, Attn: Technical Coordinator.
3.1.12 operational requirements—requirements under which the platform, system, equipment, or software will be expected to operate and be maintained (for example, day/night, all weather operation, sea state, speed, endurance) while completing a specific mission or missions.

3.1.13 panel layout drawings—detailed drawings that include such features as: a scale layout of the controls and displays on each panel or an item of equipment such as a shipboard command console; a description of all symbols used; identification of the color coding used for displays and controls; the labeling used on each control or display; and the identification of control type (for example, alternate action or momentary), also screen layouts for software generated displays.

3.1.14 platform—the major hardware (for example, ship, off-shore rig, barge, submarine) on, or in which, the individual equipment, system, or software will be installed or added.

3.1.15 spatial relationships—placement of multiple but separate components of a system together, so it is visually obvious that the components are related and used together, or placement of identical components used on multiple systems to provide the user with a spatial clue as to where the components are located.

3.1.16 subtask—activities (perceptions, decisions, and responses) that fulfill a portion of the immediate purpose within a task (for example, remove washers and nuts on the water pump).

3.1.17 system—a composite of subsystems, including equipment, communications, software, and personnel that either independently, or in conjunction with other systems, performs functions.

3.1.18 system analysis—a basic tool for systematically defining the roles of and interactions between the equipment, personnel, communications, and software of one or more systems. It is an iterative process, requiring updating. Used in the early phases of design, it can be useful in allocating assignment of tasks to personnel, equipment, software, or some combination thereof. Done in later design stages, it can serve as the basis for the arrangement of equipment and work stations.

3.1.19 task—a composite of related activities (perceptions, decisions, and responses) performed for an immediate purpose, written in operator/maintainer language (for example, change a water pump).

3.1.20 task analysis—a method used to develop a time-oriented description of the interactions between the human operator/maintainer and the equipment or software in accomplishing a unit of work with a system or individual piece of equipment. It shows the sequential and simultaneous manual and intellectual activities of personnel operating, maintaining, or controlling equipment, in addition to sequential operation of the equipment.

3.1.21 task element—the smallest logically and reasonably definable unit of behavior required in completing a task or subtask (for example, apply counterclockwise torque to the nuts, on the water pump, with a wrench).

3.1.22 vendor drawings—design drawings prepared by the manufacturer of an individual piece of equipment which is purchased for installation aboard a ship or other marine platform.

4. Summary of Practice

4.1 Human Engineering Program Plan—The human engineering program plan, in accordance with the requirements of this practice and the equipment or ship specification, shall include the tasks to be performed, human engineering milestones, level of effort, methods to be used, design concepts to be used, and the test and evaluation program, in terms of an integrated effort within the total project.

4.2 Quality Assurance—Verification of compliance with the requirements of this practice and other human engineering requirements specified by the contract will be the responsibility of the procuring activity. Human engineering performed during the development program by a contractor or subcontractor shall be demonstrated to the satisfaction of the procuring activity at the scheduled design and configuration reviews and inspections, as well as during development test and evaluation inspections, demonstrations, and tests.

4.3 Nonduplication—The efforts performed to fulfill the human engineering requirements specified herein shall be coordinated with, but not duplicate, efforts performed in accordance with other requirements. Necessary extensions or transformations of the results of other efforts for use in the human engineering program will not be considered duplication. Instances of duplication or conflict shall be brought to the attention of the procuring activity.

4.4 Cognizance and Coordination—The human engineering program shall be coordinated with maintainability, system safety, reliability, survivability/vulnerability, and integrated logistic support, as well as other human factors functions, such as life support and safety, personnel selection, preparation of job aids, and training. Results of human engineering analysis or lessons learned information shall be incorporated into the logistic support analysis as applicable. The human engineering portion of any analysis, design and development, or test and evaluation program shall be conducted by, or under the direct cognizance of, personnel properly trained and experienced in human engineering and assigned the human engineering responsibility by the contractor or subcontractor.

5. Significance and Use

5.1 Intended Use—Compliance with this practice will provide the procuring activity with assurance that the operator/maintainer will be efficient and effective in the operation and maintenance of systems, equipment and facilities. Specifically, it is intended to ensure that:

5.1.1 System performance requirements are achieved by appropriate use of the human component.

5.1.2 Proper design of equipment, software and environment permits the personnel-equipment/software combination to meet system performance goals.

5.1.3 Design features will not constitute a hazard to personnel.
5.1.4 Trade-offs between automated versus manual operation have been chosen for peak system efficiency within appropriate cost limits.

5.1.5 Application of selected human engineering design standards are technically adequate and appropriate.

5.1.6 Systems and equipments are designed to facilitate required maintenance.

5.1.7 Procedures for operating and maintaining equipment are efficient, reliable and safe.

5.1.8 Potential error-inducing equipment design features are eliminated, or at least, minimized.

5.1.9 Layouts and arrangements of equipment afford efficient communication and use, and

5.1.10 Contractors provide the necessary, technically qualified manpower to accomplish the objectives listed.

5.2 Scope and Nature of Work—The human engineering effort shall include, but not necessarily be limited to, active participation in three major interrelated areas of platform, system, and equipment development.

5.2.1 Analysis—Starting with a mission analysis developed within baseline operational requirements, the functions that must be performed by the system in achieving its mission objectives shall be identified and described. These functions shall be analyzed to determine the best allocation to personnel, equipment, software, or combinations thereof. Allocated functions shall be further dissected to define the specific tasks that must be performed to accomplish the functions. Each task shall be analyzed to determine the human performance parameters, the system/equipment/software capabilities, and the operational/environmental conditions under which the tasks are conducted. Task performance parameters shall be quantified, where possible, and in a form permitting effectiveness studies of the crew-equipment/software interfaces in relation to the total system operation. Human engineering high risk areas shall be identified as part of the analysis.

5.2.2 Design and Development—Design and development of the equipment, software, systems, and total platforms requiring personnel as operators or maintainers, or both, shall include a human engineering effort that will ensure that adequate and appropriate human engineering design standards are incorporated into the overall engineering design. Such standards may be specifically stated in the system equipment, software, or facilities acquisition specifications, or they may be generated from the analysis work completed prior to design and development.

5.2.3 Test and Evaluation—Test and evaluation shall be conducted with the newly designed equipment, software, facilities, and environment to verify that they meet human engineering and life support criteria and are compatible with the overall system requirements. This shall include periodic on-site checks of the platform, systems, equipment, software, or facilities during construction to ensure that changes are not made during construction that would degrade earlier human engineering efforts.

6. Human Engineering Activities

6.1 Scope—The human engineering program shall include the following activities:

6.1.1 Operational Requirements (OR)—Operational requirements (ORs) are established first to define the parameters within which the individual equipment, system, or total platform shall be expected to perform. ORs shall be expressed in such terms as the weather conditions under which it must operate (for example, rain, snow, sea state limits); number of days it must operate without being refueled or resupplied; and maximum number of personnel that will be available to operate and maintain the hardware. Human engineering shall be considered in the development of ORs, especially when the ORs include requirements on the number, type, or training of operators or maintainers, or both.

6.1.2 Mission Requirements Analysis—Mission requirements define the performance parameters of the equipment, system, or total platform in greater detail than that provided by the ORs, and in terms of specific activities the hardware/software is supposed to accomplish. Human engineering shall be involved in establishing the mission requirements since the human’s capabilities or limitations may well be a controlling factor regarding whether or not the mission requirements can be met.

6.1.3 System Requirements Analysis—System requirements analyses define the specific systems that will be needed to successfully complete each of the missions delineated above. Human engineering shall be involved in establishing system requirements, since some systems can require greater numbers of personnel and higher skill levels for operators or maintainers than others. Human engineering data from existing systems similar to those being proposed for the new design may be used as a baseline in defining the new system requirements.

6.1.4 Function Definition—The functions that must be performed by each system to achieve the desired mission objectives shall be defined. This definition shall be done without consideration as to whether the function will be performed by a human, by a machine, or by a combination of the two. Functions shall be stated as a required action (for example, monitor, receive, communicate, view, send, calibrate). Functional block diagrams shall be used, as appropriate, as a presentation tool. Functional definitions shall be as detailed as is necessary to permit the successful allocation of the functions. The transfer and processing of information (for example, verbal communications, electronic transmissions, printed material) shall be identified as a function but without reference to specific machine or human involvement. Human engineers shall be involved in identifying functions, since this activity serves as the base for the next step, which includes major participation by human engineering.

6.1.5 Function Allocation—Each function identified from the previous step shall be assigned to be machine implemented, performed by software, reserved for the human operator/maintainer, or performed by some combination thereof. Human engineering specialists shall participate in the function allocation process to ensure that each function assigned to the human is within the human’s capability. Known human engineering experiences with man-machine functional allocations on existing equipments, systems, or platforms similar to those under evaluation; personal human engineering experience in the function allocation field; and available information on human
physical and psychological performance capabilities shall be used when applicable in determining function allocations.

6.1.6 Equipment Selection—Hardware and software shall be selected to perform those functions assigned to them from the function allocation activity. Human engineering principles and design standards shall be included, along with other design considerations, in identifying and selecting that hardware/software. Human engineers shall ensure that the equipment provides the human with the opportunity to complete those functions assigned to the operator/maintainer, and that it complies with all of the applicable design criteria contained in Practice F 1166, as well as other human engineering design criteria contained in the contract, or in other human engineering design standards referenced in the contract. Known human engineering problems with equipment now in service (for example, information from equipment casualty reports or personnel injury data associated with equipment failure) is similar to that being considered, personal experience with applying human engineering design criteria to equipment design, and review of potential supplier engineering data are examples of the human engineering resources that shall be used in assessing the acceptance of the selected equipment from a human engineering viewpoint.

6.1.7 Human Engineering System Analysis Report (HESAR):

6.1.7.1 HESAR (TYPE 1)—Type 1 HESARs, which are prepared early in the design process (for example, during feasibility design), shall allow for the evaluation of the appropriateness and feasibility, from a human engineering perspective, of the mission, system, and functional requirements, and to serve as one basis for decisions made during the functional allocation effort. The HESAR shall contain the results of the mission, system, and functional requirements analyses and describe the human engineering rationale for, or contribution to, each. In addition, the potential impact, or the proposed use, of these analyses for future human engineering activities (for example, allocation of functions, equipment selection, detail design of equipment, arrangement of spaces or compartments) shall be discussed. The objective of the early HESAR shall be to demonstrate that human engineering considerations have been adequately addressed in the establishment of the mission, system, and functional requirements, and that there exists a sound basis on which to allocate the functions, select the equipment, and perform the detail design of the individual piece of equipment, system, or total platform.

6.1.7.2 HESAR (TYPE 2)—A Type 2 system analysis, completed late in the design process (for example, during development of construction drawings or production drawings) shall be done to provide a basis on which to base a particular equipment design, or system or compartment arrangement. In completing a Type 2 system analysis the following factors shall be considered, and shall be discussed in the HESAR: (1) description of the equipment, console, compartment, system, or work station on which the analysis was conducted, (2) externally imposed design requirements or criteria over which the human engineer had no control (for example, number of operators/maintainers, specific types and numbers of consoles, previously determined man-machine function allocations, predetermined locations of hardware), (3) communications requirements (for example, telephone, voice, sound powered phones, electronic), (4) work environment, (5) mission, system, backup, and functional requirements, and (6) human physical and psychological capabilities within the context of the existing design parameters. In conducting the analysis, consideration shall be given to such issues as projected work loads for each manned position; the kind, amount, and criticality of the information that goes into, and out of, each operator/maintainer station; the need for direct voice or visual communication between manned positions; location and suitability of backup equipment in case the primary hardware fails; and the interactions that are required between personnel or equipment, or both. Using the completed analysis, the human engineer shall participate in establishing the final design or arrangement of a piece of equipment, a system, or the total platform.

6.1.8 Task Analysis:

6.1.8.1 Concurrence and Availability—All task analyses shall be modified as required to remain current with the design effort and shall be available to the procuring activity as requested.

6.1.8.2 Gross Task Analysis (GTA)—A GTA consists of defining the major tasks required of the human operator/maintainer to complete each function identified and allocated to the human during the functional allocation activity (see 6.1.5). The GTA shall present these tasks in the sequence in which they must be completed and against an established time line reference. Information flows into, or out from, the human shall be included as a task. The GTA shall include both manual and cognitive tasks, and shall be written in operator/maintainer language (for example, change fuel pump, steer ship on constant heading, calculate fuel consumption rate). Where GTAs are required they shall be performed for both normal and emergency operating conditions. The GTAs shall be used to determine, to the extent practicable, whether the system performance requirements (see 6.1.3) can be met with the function allocations, backup facilities, and equipment selections that have been previously made. These analyses shall also be used as basic information for developing preliminary manning levels; equipment procedures; personnel skill, training, and communication requirements; and as logistic support analysis inputs. Personal experience of the human engineering analyst in the preparation of GTAs, information from equipment vendor operation and maintenance manuals, inputs from the design engineers (either at the procuring activity or the contractor) of the system(s) or equipment under evaluation, and established tasks on equipment similar to that under investigation are all resources that shall be used as appropriate in the creation of GTAs. GTAs shall be presented in diagrammatic form (for example, operational sequence diagrams) unless otherwise approved by the procuring activity.

6.1.8.3 Critical Task Analysis (CTA)—Those gross tasks identified in the GTA that require critical human performance (for example, no deviation from a fixed sequence; task completion within a fixed, and limited, time frame; accurate setting or reading of an important control or display), reflect possible unsafe practices, or that are subject to promising improvements
in operating efficiency shall be identified and further analyzed upon approval of the procuring activity. CTAs require detail to the subtask (for example, remove hose clamp from hose on the discharge side of water pump), or even task element level (for example, turn screw on the hose clamp on discharge side of water pump counterclockwise with Phillips head screwdriver). Other inputs which shall be made to a CTA include: (1) information required by the operator/maintainer for task initiation, (2) all information available to the operator/maintainer, (3) cognitive functions required of the operator/maintainer to process or act on the information, (4) actions required by the human based on the cognitive processes, (5) workspace envelope required by the actions, (6) workspace available, (7) frequency and accuracy required of the actions, (8) feedback required to the operator/maintainer regarding the adequacy of his/her actions, (9) tools or equipment, or both, required by the human, (10) job aids or references required, (11) number of personnel required or provided, as well as their specialty and experience, (12) communications required, and the types of communications, (13) safety hazards involved, (14) operational requirements of the human (for example, hours on duty, number of repetitive motions), (15) backup facilities available, and (16) operator interaction where more than one person is involved. The format shall include a time line base for presenting the information listed herein. Task analysis may be produced by automated programs after review and approval of the programs by the procuring activity.

6.1.9 Human Engineering Design—Human engineering principles and design standards shall be applied to the design of all compartments, spaces, systems, individual equipment, work stations, and facilities in which there is a human interface. Drawings, specifications, analyses, or other documentation shall reflect incorporation of these human engineering principles and standards. Where specific design criteria are required, they shall conform to Practice F 1166 or other human engineering criteria required by the contract. Design of the compartments, spaces, equipment, systems, work stations, and facilities shall provide for both normal and emergency conditions, and shall consider at least the following where applicable:

6.1.9.1 Environmental conditions, such as temperature, humidity, air flow, noise and illumination levels, and atmospheric contaminants,

6.1.9.2 Weather and climate, such as rain, snow, and ice,

6.1.9.3 Platform motion (for example, ship roll and pitch),

6.1.9.4 Space (that is, access) requirements for personnel to perform operations and maintenance, keeping in mind the special clothing or protective gear they may be wearing and the tools they may be carrying,

6.1.9.5 Safe and efficient walkways, ladders, work platforms, and inclines,

6.1.9.6 Adequate physical, visual, and auditory links between personnel, and between personnel and their equipment so that reach and visual envelopes are within standard limitations,

6.1.9.7 Provisions to minimize physical or emotional fatigue,

6.1.9.8 The effects on physiological and psychological performance due to special clothing, or chemical, biological, and radiological (CBR) protective suits,

6.1.9.9 Provisions to maximize cultural expectations and spatial relationships in the design,

6.1.9.10 Equipment removal and stores handling provisions,

6.1.9.11 Crew safety requirements, and

6.1.9.12 The range in physical size (for example, 5th to 95th percentile dimensions) and mental capabilities of the anticipated users of the equipment.

6.1.9.13 The adequacy of including human engineering principles and design standards into the overall design effort shall be evaluated during design reviews. Where such reviews involve a contractor or subcontractor, the individuals assigned the human engineering responsibilities by these organizations shall participate in the reviews. At quarterly design reviews these individuals shall provide the same type of presentation as is made by the other engineering disciplines.

6.1.10 Application of Lessons Learned Information—Information on known or suspected human engineering problems from past or existing equipments, systems, or total platforms similar to that under design shall be obtained and used in the design of the new equipment, system, or platform. This information shall be acquired from such sources as: personal inspection of current hardware, system, or platform (for example, conduct a ship check or ship survey), interviews with past or current operators or maintainers, or both, a review of sea trial deficiency cards, discussions with past or current designers of similar equipments, systems, or platforms, and investigation of personnel injury or equipment casualty reports, or both. Any summation reports prepared from the acquisition of this data shall provide the information by equipment, system, or ship compartment and shall include the ship work breakdown structure (SWBS) number or other corresponding specification section for each identified human engineering problem.

6.1.11 Engineering Design Drawings—Human engineering principles and design standards shall be reflected in the engineering design drawings produced for marine systems and equipment. These principles and standards shall be incorporated in all engineering drawings that involve a human interface and are developed during the various design phases. Specific types of drawings to which the human engineering principles and design standards shall be applied include: overall platform (for example, ship, off-shore rig, barge) arrangement drawings, individual compartment or space arrangement drawings, zone arrangement drawings, console or work station panel layout drawings, individual equipment design drawings, piping arrangement drawings, and other drawings depicting the design or arrangement, or both, of equipment requiring operation or maintenance, or both, by humans. The drawings shall comply with the applicable criteria contained in Practice F 1166 or other human engineering design standards, or a combination thereof, as specified in the contract.

6.1.11.1 Where the drawings are produced by a contractor, a specific list of the engineering drawings or a description of the types of drawings that will receive human engineering input
shall be included in the contractor’s human engineering program plan (HEPP). Personnel assigned human engineering responsibility by the contractor shall approve all drawings included in the HEPP list before the drawings are released for production.

6.1.12 Human Engineering in Vendor Hardware/Software—Human engineering principles and design criteria from Practice F 1166 (or other approved design standards) shall be incorporated into hardware and software purchased by the contractor for inclusion on a marine platform or major system. The human engineering program plan shall include a list of the hardware/software items on which human engineering principles and design criteria will be imposed. The contractor shall also ensure that the vendor hardware/software complies with the design standards of Practice F 1166 after installation in or on the platform or system.

6.1.13 Studies, Experiments, and Laboratory Tests—The contractor shall conduct experiments, tests (including dynamic simulation per 6.1.14), and studies required to resolve human engineering and life support problems specific to the system. Human engineering and life support problem areas shall be brought to the attention of the procuring activity, and shall include the estimated effect on the system if the problem is not studied and resolved. These experiments, tests, and studies shall be accomplished in a timely manner, that is, such that the results may be incorporated into the design. The performance of any major study effort shall require approval by the procuring activity.

6.1.14 Dynamic Simulation Studies—Dynamic simulation studies shall be used as a human engineering design tool when necessary for the detail design of equipment requiring critical human activity (for example, precise ship maneuvering or handling tasks). If such studies are completed, the simulation hardware/software should be evaluated as a training tool as well, and shall be addressed in the dynamic simulation plan. No dynamic simulation studies shall be performed without prior approval of the simulation plan by the procuring activity.

6.1.15 Mockups and Models—Models and mockups built to resolve access, workspace design, equipment arrangements, or other human engineering problems shall be constructed at the earliest practical point and well before fabrication of the compartment, system, or equipment. The proposed human engineering program plan shall specify which models and mockups the contractor proposes to use for human engineering purposes. Mockups shall be full scale and models shall be built to SNAME Sample Model Specification for Human Engineering Purposes—Technical and Research Bulletin 4-22. For models and mockups specified primarily for human engineering use, the workmanship shall be no more elaborate than is necessary to determine the adequacy of size, shape, arrangement, access, or panel content of the equipment for human use. Models and mockups shall be constructed as simply and inexpensively as is compatible with the objective and use. They shall be updated regularly to reflect the latest designs. Upon approval by the procuring activity, scale models may be substituted for mockups. The models and mockups shall be available for inspection as determined by the procuring activity. Mockups and models may be disposed of only with the approval of the procuring activity.

6.1.16 Human Engineering in Performance and Design Specifications—Where the contractor prepares a specification for the design, development, construction, or acquisition of a marine platform, system, piece of equipment, facility or software, it shall conform to applicable human engineering criteria of Practice F 1166 and other human engineering criteria specified by the procuring agency.

6.1.17 Equipment Procedure Plates and Manuals—The contractor shall apply human engineering principles and criteria to the development of procedures and manuals for operating, maintaining, or otherwise using the system and equipment. For individual procedure plates (for example, lubrication charts, hazard warnings, operating instructions, schematics), mounted at the equipment, they shall comply with the design requirements in Practice F 1166. For computer systems, human engineering shall be applied throughout software program planning and development. This effort shall be accomplished to ensure that the procedures are concise, unambiguous, and easy to read and follow with a consistent presentation format, especially for the hazard identification statements. The results of this effort shall be reflected in the preparation of user-oriented operational, training, and technical plates, manuals, and other publications.

6.1.18 Human Engineering Design Approach Document (HEDAD)—Two types of HEDADs shall be prepared: the HEDAD-operator (HEDAD-O) and the HEDAD-maintainer (HEDAD-M).

6.1.18.1 HEDAD-O—The HEDAD-O shall describe the as-built system or equipment (for example, console, specific work station, compartment arrangement, lube oil system) from an operator’s perspective. The system or equipment shall be described in detail (for example, each display or control on a console; each pump, controller, and meter in the lube oil system) explaining the design, layout, and location of each component from a human engineering perspective. The HEDAD-O shall describe where each component is located, why it was designed the way it appears in the finished product, and why the as-built arrangement was selected (that is, the human engineering rationale). The HEDAD-O shall provide the procuring activity with sufficient detail to evaluate the as-built system or equipment to ensure that it is operable and complies with the human engineering requirements contained in the system or equipment design and acquisition contract.

6.1.18.2 HEDAD-M—The HEDAD-M shall be prepared in the same manner and detail as the HEDAD-O but shall describe the system or equipment from a maintenance perspective. In addition to a description of each component, such items as access openings, test or calibration points, lubrication fittings, and other maintenance specific design features shall be identified and discussed. The HEDAD-M shall be in sufficient detail to allow the procuring activity to determine that the system or equipment is maintainable and complies with the human engineering requirements contained in the design and acquisition contract.
6.1.18.3 General Requirements—The systems or equipment that will receive a HEDAD during design and development shall be listed in the contractor’s human engineering program plan along with a brief rationale as to why the particular HEDADs were selected (the explanation is required only if the contractor was allowed to select the HEDADs). A brief discussion of the contractor’s proposed methodology for completing the HEDADs shall also be included in his plan. The contractor shall include drawings (for example, console panel layouts; system arrangement; plan, section, and elevations for work stations), photos, or other visual aids as necessary to assist in describing the system or equipment.

6.1.19 Human Engineering Progress Report (HEPR)—HEPRs shall be prepared by the contractor and submitted on a regular basis to the procuring activity. The reports shall be concise, but in sufficient detail to allow the procuring activity to assess the adequacy of the contractor’s human engineering program. Information on work accomplished, human engineering problems encountered and solutions generated, as well as projected activity for the next reporting period shall be included.

7. Test and Evaluation

7.1 Human Engineering in Test and Evaluation—The contractor shall establish and conduct a test and evaluation program to:

7.1.1 Demonstrate conformance of marine system, equipment and facility design to human engineering design criteria.
7.1.2 Confirm compliance with overall system performance requirements where personnel could be a performance determinant.
7.1.3 Secure quantitative measures of system performance which are a function of the human interaction with equipment, and
7.1.4 Determine whether undesirable design or procedural features have been introduced, but went undetected, during design and development. The test and evaluation effort may be required at various stages in system, subsystem, or equipment development but these shall not preclude final human engineering verification of the complete system. The human engineering test and evaluation program shall include both operator and maintenance tasks as described in a test plan approved by the procuring activity.

7.2 Planning—Human engineering testing shall be incorporated into the total platform, or individual system, hardware, or software test and evaluation program. The test requirements shall be satisfied through integration with the equipment engineering acceptance tests, contractor demonstrations, ship trials, research and development acceptance tests, or dedicated human engineering tests using actual hardware or mockups. Compliance with human engineering requirements shall be tested as early as possible. Human engineering findings from design reviews, mockup inspections, demonstrations, and other early engineering tests shall be used in planning and conducting later tests.

7.3 Human Engineering Test Plan—A human engineering test plan (HETP) shall be prepared describing when, how, and who will complete the human engineering test and evaluation program. For smaller or less complex systems, the HETP may be submitted as part of the HEPP. If the plan is prepared by a contractor, it shall be approved by the procuring activity before the start of testing. The plan shall describe the proposed test and evaluation program in sufficient detail to permit the procuring activity to determine if the test program will meet the objectives listed in 7.1. The plan shall be prepared so that the human engineering tests will involve individuals representative of the intended user population, performing actual (or simulated) operational and maintenance tasks, under actual or realistic operating environments, and using garments and equipment appropriate to the tasks involved in the tests. The plan shall require that all failures occurring during test and evaluation shall be subjected to a human engineering review to differentiate between failures caused by equipment alone, personnel-equipment incompatibilities and those caused by personnel alone. The contractor shall identify and notify the procuring activity of suspected design conditions which contributed substantially to or induced human error and shall propose appropriate solutions to these conditions.

7.4 Human Engineering Test Reports (HETR)—An HETR shall be prepared for each human engineering test conducted. It shall describe the equipment tested, the test conditions, test subjects, test procedures, results, and design recommendations coming from the test results. For small or less complex systems, the HETR may be submitted as part of the HEPR.

8. Documentation

8.1 Data Requirements—Human engineering data requirements shall be as specified by the contract. See Appendix X2.

8.1.1 Traceability—The contractor shall document his human engineering efforts to provide traceability from the initial identification of human engineering requirements during analysis or system engineering, or both, through design and development to the verification of these requirements during test and evaluation of approved design, software, and procedures. Each human engineering input made during design, construction, and test shall be recorded to indicate that the input was included in the finished product or rationale for exclusion.

8.1.2 Access—All data, such as plans, analyses, design review results, drawings, checklists, design and test notes, and other supporting background documents reflecting human engineering actions and decision rationale, shall be maintained and made available at the contractor’s facilities to the procuring activity for meetings, reviews, audits, demonstrations, test and evaluation, and related functions.

9. Keywords

9.1 drawings; equipment; human engineering; human engineering program; human factors; program; ships; system
X1.1 Scope

X1.1.1 It is not expected nor desired that every human engineering activity contained in this practice should be completed on every marine contract. Therefore, this practice is deliberately constructed to allow the procuring activity, (or the contractor, if directed to do so), to choose only those activities that will directly benefit each contract. This appendix provides guidance and selection criteria to assist in picking from all the human engineering activities described in this practice only those that are necessary for each contract.

X1.2 Tailoring

X1.2.1 General

The underlying purpose for any human engineering program on an equipment, system, or platform design and development contract is to influence the design of the hardware/software, not to produce paper. Lengthy studies, unnecessary analyses, wordy progress reports, simulation studies that make no direct contribution to design, unproductive human engineering test programs, and system analysis studies done after design is frozen are wasteful and undesirable. Thus, every human engineering activity included in a contract must be directly oriented to maximizing the human’s contribution to the overall successful operation of the hardware/software under design. That is why decisions to include human engineering and which activities, must be done by human engineering specialists, either at the procuring activity, or within the contractor’s organization.

X1.2.2 Selection Guide:

X1.2.2.1 General

The decision as to whether or not to invoke this practice as a mandatory provision on design and development contracts for marine equipments, systems, or platforms is dependent on several factors including: (1) the type of hardware/software (in terms of operation and maintenance requirements), (2) the degree to which the human is involved in the operation or maintenance of the hardware/software, and (3) the point in the design process when human engineering becomes involved. Use of any, or all, of the requirements in this practice should not normally depend on hardware size (that is, big ship versus little ship), system complexity, hardware duty cycles, number of human operators/maintainers involved, or, within practical limits, the contract type, cost, duration, or size of production lots. These factors may influence the kind, or number, of human engineering activities selected for the contract, but not the decision to include or exclude a human engineering program in the contract.

X1.2.2.2 Specification Requirement

For most contracts, but particularly fixed price contracts, the specification, circular of requirements (COR), or statement of work (SOW) shall clearly define which of the human engineering activities from this practice shall be performed by the contractor. The responsibility for selecting these activities must rest with the human engineering specialists within the procuring activity. For cost plus contracts, the contractor is sometimes given the responsibility to define the human engineering program, with procuring activity approval. Therefore, this tailoring guide should be used by whomever shapes the human engineering program.

X1.2.2.3 Selection Guidelines (General)

Generally, human engineering activities from this practice should not be included in a contract that covers parts, subassemblies, or other small components (for example, bearings, transformers, wheels). Likewise, the practice should normally not be considered for use in hardware/software development contracts where human involvement or interface is obviously insignificant. In contrast, if the request for proposals (RFP) specification, or other contract documentation states performance requirements or goals (for example, accuracy, time limits, maximum error rates, mean time to repair) to which the human operator/maintainer can reasonably be considered to contribute, then this practice should be used.

X1.2.2.4 Phases of the Acquisition Process

There are distinct phases in the acquisition of a new platform (ship), system, or equipment. For a system or equipment these are normally concept exploration, demonstration and validation, full-scale development, and production and deployment. For a ship these four phases are feasibility studies, preliminary design, contract design, and detail design and construction.

X1.2.2.5 Selection Guidelines (Particular)

A more specific guideline for selecting particular activities from the practice is included in Table X1.1. The table shows the human engineering activities and requirements, identified by paragraph number and title. It also shows the four stages of the design process commonly found in the marine design and development world. For each intersection of design phase and human engineering activity, a letter indicates whether the activity is normally required (R), possibly completed (P), or normally not completed (N) for that design phase. A (—) implies that the activity discussed in the practice is given for informational purposes only and not as a contract requirement. Table X1.1, therefore, provides some guidance as to where along the design and development process each of the human engineering activities should be applied.

X1.2.2.6 Evolutionary Design and Development

The use of Table X1.1 is directed at the design and development of new equipments, systems, or platforms. However, much of the design effort in the marine world is devoted to improving one particular piece of equipment, or upgrading one, or a few, compartments on a platform (for example, overhaul of a ship engine room or conversion of a propulsion plant). It is also common to take an existing system (for example, lube oil, water purification, sanitary treatment) or platform (that is, ship) and design and build a new one while...
using much of the old one as a baseline design. Under these circumstances it is normal procedure to apply the human engineering activities listed in the practice to only those equipments, systems, or platform alterations which are being changed from the baseline. As for the specific activities to be included, those listed for detail design and construction are the most likely to be appropriate.

X1.2.2.7 Summary

Although the general and particular guidelines provided above can be helpful in tailoring the human engineering requirements contained in this practice to a specific design and development contract, they are not foolproof. That is why it is so important to have the tailoring done by a human engineering specialist with experience in the marine design and construction business. No tailoring guide can be as effective in defining a good human engineering program as the academic and experiential background possessed by a human engineering specialist in the marine world.

### TABLE X1.1 Human Engineering Application Matrix

<table>
<thead>
<tr>
<th>Section in F 1337</th>
<th>Title of Section</th>
<th>Concept/Feasibility</th>
<th>Validation/Preliminary</th>
<th>Development/Contract</th>
<th>Production/Design/Construction</th>
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<tr>
<td>1</td>
<td>Scope</td>
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<td>R</td>
<td>R</td>
<td>R</td>
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<td>Referenced Documents</td>
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<td>Terminology</td>
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<td>4</td>
<td>Summary of Practice</td>
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<td>Quality Assurance</td>
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<tr>
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<td>5.2</td>
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X2. DATA REQUIREMENTS

X2.1 Government Data Requirements—For government procurements, in which the use of a Contract Data Requirements List (DD 1423) is a requirement, the Data Item Descriptions (DID) should be used when applicable.

X2.2 Commercial Data Requirements—For commercial procurements, the data requirements should be included in the contract in the manner commonly used for other data requirements.

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Standard Guide for
Main Propulsion Medium Speed Marine Diesel Engines
Covering Performance and Minimum Scope of Assembly

This standard is issued under the fixed designation F 1338; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers performance and minimum scope of assembly of all medium speed marine diesel engines intended for main propulsion of single or multiple screw propelled marine vessels or for vessels using other than screw propeller-type main propulsion.

1.2 This guide is intended to supplement the regulations of legally constituted regulating authorities. In the event of any conflict, which may become apparent after publication of this guide, with such legally constituted regulations, the latter shall take precedence, as may be applicable within the jurisdiction of such authorities and specific to each case, unless such latter regulations are formally waived by proper cognizant authority.

1.3 This guide is not intended to relieve the purchaser of the obligation fully to advise the engine builder of all of the purchaser’s unique operational considerations to allow those considerations to be satisfied.

2. Referenced Documents

2.1 ABS Standard: Rules for Building and Classing Steel Vessels
2.2 IEEE Standard: Standard No. 45, Recommended Practice for Electrical Installations on Shipboard
2.3 ISO Standard: ISO 3046/1 Reciprocating Internal Combustion Engines—Performance
2.4 Code of Federal Regulations: United States Coast Guard Regulations as Published in Code of Federal Regulations No. 46 (CFR 46)

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 diesel engine—a reciprocating or rotary engine in which ignition of the main fuel charge, as it is introduced to the combustion chamber, shall be by the heat of compression of the charge of combustion air, during regular operation of the engine from idle speeds up to full speed, regardless of whether miscellaneous methods to augment such heat of compression are used to facilitate starting of the engine under normal conditions or under low ambient temperature conditions or low intake air temperature conditions. Engines that are designed to operate with a continuously hot spot or bulb or other device to facilitate ignition or combustion, or both, of low cetane fuels, or any fuels slow to ignite or to burn, or both, shall be considered to be diesel engines for purposes of this guide.

3.1.2 engine assembly—contains, but is not necessarily limited to, that apparatus secured to or applied to a basic engine, which is needed to make the basic engine operable and capable of developing its rated power as indicated or to be indicated on the engine nameplate.

3.1.3 fuel map—a chart on which there is displayed a family of curves of various constant rates of specific fuel consumption, each curve of the family being plotted on a grid, the abscissa of which is engine r/min and the ordinate of which is brake horse power or brake mean effective pressure.

3.1.4 medium speed diesel engine—all diesel engines with crank-shaft rotative speeds encompassed by the maximum continuous speed bracket of 400 to 600 r/min (see Appendix X1).

4. Significance and Use

4.1 Comparison of brake horsepower developed and of specific fuel consumption rates from engine to engine may be made by use of data based upon a standard for composition of an engine assembly.

4.2 The purchaser of the engine assembly will be fully advised of the minimum scope of assembly which the purchaser may rightfully expect to be encompassed by a response to a request for quotation and to be delivered in response to a...
purchase order unless the engine builder in the proposal or in the offer to sell has clearly advised otherwise.

4.3 It will be made apparent to the purchaser that additional auxiliary and accessory equipment will be needed to supplement the defined engine assembly when full consideration is given to the application of the engine assembly as a prime mover in a specific vessel.

5. Regulations, Conventions, and Standards

5.1 Specific—The regulations, conventions, and standards to which a commercial marine vessel may be subject in regard to the main propulsion prime movers will vary depending upon the flag of registry of the vessel.

5.2 General:

5.2.1 There may be regulations, conventions, and standards and such applicable international treaties to which the country of registry may subscribe which shall be taken as forming a part of this guide to the extent specified herein and to the extent they shall be deemed applicable to the vessel by the country of registry.

5.2.2 Typical examples applicable to vessels of the United States of America registry are as follows: Institute of Electrical and Electronic Engineers Standard No. 45 (IEEE No. 45); Rules of the American Bureau of Shipping; Rules of the United States Coast Guard as printed in various Part Numbers of Title 46 CFR of the United States of America and formerly commonly known as CG-115 (Marine Engineering Regulations, also known as Sub-chapter F); and CG-259 (Electrical Engineering Regulations, also known as Sub-chapter J).

6. Ordering Information

6.1 Orders for machinery under this guide shall include the following:

6.1.1 ASTM designation, title, and date of this guide.

6.1.2 Quantity, and

6.1.3 Packaging or packing and preservation requirements, or both.

7. Minimum Scope of Assembly

7.1 Each engine assembly to meet this guide shall include the following:

7.1.1 The basic power producing unit or engine, be it that formed by an internal combustion reciprocating engine or by an internal combustion rotary engine.

7.1.2 An engine-mounted intake manifold or manifolds to conduct air for combustion to the basic engine, with such manifold properly secured to the basic engine and properly gasketed for the service intended, which is the efficient conduction of air to the basic engine when it is installed in a marine environment for main propulsion of a vessel.

7.1.3 An engine-mounted exhaust manifold properly insulated (including insulation by use of a water jacket application) as may be required by laws and regulations discussed in 2.2 herein [such as the requirements of USCG-115, paragraph 56.50-1 (k), Parts 50–60, Title 46 CFR].

7.1.4 One or more engine-driven and engine-mounted scavenging air blowers, if required by engine design concept, or one or more single shaft assemblies of an exhaust gas-driven turbine and combustion air blower, or both, if required by engine design concept, to provide a supply of air for scavenging or supercharging, or both, and for basic combustion of the fuel. The single-shaft exhaust gas-driven turbochargers may be engine mounted or separately mounted. The intended method of mounting of such turbochargers shall be clearly described to the prospective purchaser by the engine builder in any response to an inquiry so that the impact on installation cost and responsibility, if any, will be apparent. Turbocharger arrangements, for water-washing or other routine maintenance procedures recommended by the engine builder, shall be provided.

7.1.5 An engineered arrangement of sufficient drilled and tapped holes, properly plugged during shipment, to allow measurement of combustion air and exhaust gas temperatures and pressures at appropriate points in the engine assembly.

7.1.6 One or more air cooler assemblies, if required by engine design concept and power rating, designed to accept all of the air for combustion and scavenging and to cool such air to appropriate temperatures as required by design of the basic engine and by the predicted range of brake horsepower output and concurrent specific fuel consumption rate range. Following the logic of 7.1.4, the air cooler assembly might be offered as a remotely mounted device along with its associated turbochargers. If so, as in the case of the turbocharger, the intended method of mounting shall be clearly described to the prospective purchaser by the engine builder so the impact on installation cost and responsibilities, if any, will be apparent.

7.1.6.1 Such cooler assemblies, commonly referred to as intercoolers or aftercoolers, shall be arranged, if required by overall engine design and application, to limit cooling or to add heat energy to the charge of air for combustion to allow operation of the engine at low continuous power ranges as indicated by the engine builder on a chart of the descriptive curves of performance of the engine (see 4.1 and 4.2).

7.1.7 A jacket water-circulating pump and any other closed circuit fresh water pumps required for operation of the engine. If this pump is not engine mounted and engine driven as parasitic load, the specific fuel rate for the engine on the factory test stand shall be corrected logically and accurately to increase appropriately the specific fuel rate demonstrated on the factory test stand and thereby to allow comparison to other engines (see Section 8).

7.1.8 One or more pressure pumps for main engine lubricating oil supply of each engine unit and, if required by design, for piston cooling service. If this pump(s) is not engine mounted and engine driven as parasitic load, the specific fuel rate for the engine on the factory test stand shall be corrected logically and accurately to increase appropriately the specific fuel rate demonstrated on the factory test stand and thereby to allow comparison to other engines (see Section 8).

7.1.9 A full flow lubricating oil duplex discharge strainer or filter for each engine unit to transmit all oil delivered to the engine by the main lubricating oil pressure pump; or, if required by engine design, lubricating oil supplied to the subordinate and discrete systems of the engine may be supplied via an additional separate duplex lubricating oil strainer. Such strainers need not necessarily be supplied as engine mounted.
7.1.10 An integral, lubricating oil sump, suitable for operation of that engine when installed in a horizontal position but of a limited capacity with respect to total oil charge. Such a sump may be provided with two or more openings which, if left open for connection to a drain, will allow use of a remote oil sump of larger capacity as suggested by the engine builder.

7.1.11 A duplex suction strainer of mesh as recommended by the engine builder to be located on the suction side of the main lubricating oil pressure pumps. Such a strainer need not necessarily be engine mounted.

7.1.12 A force feed cylinder or valve stem lubricator system, or both, if required by engine builder’s design, or by the service intended, or both, or by main engine fuel intended, with both of the latter as stated by the purchaser.

7.1.13 Crankcase pressure relief valves or covers as recommended by the engine builder to meet standards of cognizant marine inspection and classification authority as identified by the purchaser.

7.1.14 An engine-barring device which shall be power driven unless clearly identified to the purchaser by the engine builder as required to be operated by manual effort only.

7.1.15 An engine-mounted flywheel secured to the drive end of the crankshaft complete and sufficient to carry timing marks. If required by drive system arrangement to the reduction gear (or to the propeller shafting if no reduction gear is to be used), the flywheel shall be complete and sufficient to accept mounting of the adjacent flange or coupling component. The machining of the flywheel to accept the adjacent flange or coupling component is part of an engine assembly. The associated set of bolts required shall not be part of an engine assembly.

7.1.16 Propeller Thrust Bearing—NO propeller thrust bearing shall be incorporated into the engine assembly for medium speed main propulsion marine diesel engines except as a result of a specific contractual requirement placed on the engine builder as a result of negotiation with the purchaser.

7.1.17 Governors:

7.1.17.1 The engine builder shall provide the primary engine speed governor. The actuator portion of the governor with its power unit and the speed-sensing portion shall be engine mounted. Nothing in the specification is intended to prevent off-engine location of electro/electronic portions, if any, of the governor system. The required functions or other characteristics, or both, of the governor shall be specified to the engine builder by the purchaser.

7.1.17.2 The engine builder shall provide an overspeed automatic shutdown device or overspeed self-resetting device separate and distinct from the governor of 7.1.17.1 and it shall be engine mounted.

7.1.18 Start-Stop Controls:

7.1.18.1 The engine builder shall provide an engine-mounted system either for complete local control only of the engine or adaptable for local control and remote control from the bridge or the engine room control console, or both. The scope of the remote control features required by the purchaser must be clearly presented to the engine builder in the purchase specification, and requirements of the therein identified cognizant regulatory bodies must be met by the engine builder.

7.1.19 Fuel Oil System:

7.1.19.1 An engine-mounted, engine-driven, fuel oil booster pump (service pump) shall be provided, if required, by the engine builder’s design; however, such a pump may be motor driven for this class of engine and not integral with the engine assembly as shipped. It is, however, to be an item furnished and to be treated as a parasitic load.

7.1.19.2 A duplex final fuel filter or strainer, as specified by the engine builder, shall be supplied by the engine builder. If engine mounted, it shall be properly protected for shipment so that the engine-mounted fuel distribution piping is maintained in a thoroughly clean condition during shipment and installation of the engine.

7.1.20 Engine-Mounted Piping—All required engine-mounted piping for jacket water, raw water, lubricating oil, fuel oil, starting air, control air or hydraulic oil, or a combination thereof, for controls shall be terminated in a workmanlike manner in a flange or other connection arrangement on the engine assembly, and all nonstandard companion flanges or other fittings shall be included by the engine builder.

7.1.21 All special tools not readily obtainable by an owner of a vessel but required for day-to-day maintenance efforts shall be included with the engine assembly as shipped. The engine builder shall provide a fully descriptive list of such special tools as part of a response to any request for a proposal for the machinery.

7.1.22 Spares—No spares are required as part of an engine assembly. However, governmental agencies, the purchaser, the cognizant classification society, and the engine builder all have either authority or interest to see that an appropriate set of spares is provided on board the vessel before final approval to operate is given.

7.1.23 Instrumentation:

7.1.23.1 Engine-mounted instrumentation for local observation. A set of engine-mounted instruments for local observation
shall be provided to meet regulatory body requirements and the requirements of the purchaser. Also, a tachometer drive arrangement shall be provided as well as arrangements to allow measurement of cylinder pressures using a portable pressure measuring device, but not including such device.

7.1.23.2 Engine-mounted sensors for remote readout systems are not part of the engine assembly. However, a special set of instrument wells or drilled, tapped, and plugged openings may be required on the engine-mounted piping and components to accommodate remote reading instruments, and such requirements should be developed separately by discussion between the purchaser and the engine builder.

7.1.24 Cylinder Pressure Relief Valves—Such valves are usually required by the cognizant classification society, whose requirements must be ascertained and met for any specific order for a main propulsion engine.

7.1.25 Drawings—The following should be included in the supply of an engine: engine arrangement drawing including data with respect to engine weight; location of vertical, horizontal, and longitudinal centers of gravity; principal dimensions; size and location of connection points or engine-mounted piping terminations which are to be connected to external piping, tubing, or ducts by others, as well as any special data with respect to such connections; engine bolting and chocking plan; schematic drawings of engine support piping systems showing design restrictions or data important to the installing shipyard.

7.1.26 Manuals and Books—An engine instruction manual covering all components described herein as constituting an engine assembly, and parts books of equal scope, providing information required to operate and maintain the equipment.

7.1.27 Vibration Analysis:

7.1.27.1 The engine builder shall include an analysis of the mass-elastic system of the engine with respect to torsional vibrations. When any or all of the driven equipment system is supplied by others, it is the responsibility of the purchaser to provide, in a timely manner to the engine builder, accurate and complete data with respect to such items of the driven equipment system.

7.1.27.2 Consideration of axial vibration of shafting, lateral shaft vibration, propeller excited vibration, or induced hull vibrations, or a combination thereof, are not in the province of the engine builder’s unique expertise and knowledge to the same extent as is consideration of torsional vibration. If the engine builder is to be required to accept these additional responsibilities, it should be a matter of negotiation and mutual agreement between the purchaser and the engine builder and should be an item in the contract to purchase.

8. Treatment of Parasitic Loads

8.1 General—A recognized and accepted basis, by reference to which a comparison of performance test results may be made, is necessary. The heart of such basis of comparison is consistent and accurate treatment of the parasitic loads of those items of power consuming auxiliary apparatus which are defined in Section 6 to be part of an engine assembly. In summary, such items are:

8.1.1 Scavenging air blowers,
8.1.2 Lubricating oil circulation pumps,
8.1.3 Jacket water-circulating pumps,
8.1.4 Fuel oil service (booster) pumps, and
8.1.5 Engine governor system: component(s) to actuate fuel rack controls.

8.2 If any of the above are required to allow the engine assembly to operate and are not engine driven during such factory tests as are carried out to verify engine brake horsepower and engine specific fuel consumption data, then appropriate, logical, consistent, and accurate treatment is necessary to allow comparison of performance data from engine to engine.

8.2.1 The formula or technique for such correction shall be agreed upon mutually by the potential purchaser and the responding engine builder(s) during the development of a contract to purchase. In the development of such formula, attention should be given to cost of fuel to be burned by the extraneous power source in the proposed vessel and the specific fuel rate of that extraneous source, which, in most cases, will be another prime mover or a ship’s service diesel generator set.

8.2.2 The permutations and combinations are such that detailed treatment is not feasible herein. However, a competent marine engineer can carry on such specific study or review for a purchaser.

9. Performance of an Engine

9.1 The maximum continuous rating (MCR) (see Appendix XI) of an engine shall be shown on the engine nameplate and on all appropriate engine documents. It shall be expressed in brake kilowatts (international) and in British brake horsepower units of 33 000 ft-lb/min. This dual expression of power shall be maintained herein indefinitely until adoption of the designation of power in brake kilowatts is universally and commonly accepted instead of brake horse power (British) or brake horse power (metric). It shall be that power which the engine will deliver continuously, in commercial marine service, at its flywheel (or other coupling flange) at rated revolutions per minute (r/min) when in good operating condition and under standard conditions (see Section 11) with respect to heat content of the fuel burned; and further, under standard atmospheric conditions with respect to ambient air temperature and ambient air pressure at the intake point for combustion air; and further provided that the exhaust back pressure at the exhaust outlet flange provided on the engine by the engine builder does not exceed the limit specified by the engine builder; and further provided that the pressure drop through the air intake system as measured at the air intake flange provided on the engine by the engine builder does not exceed the limit specified by the engine builder.

9.2 At any of the revolutions per minute encompassed by the bracket between maximum continuous r/min and minimum continuous r/min as defined by the engine builder and illustrated on the engine builder’s chart of the descriptive curves of performance of the engine, there shall also exist maximum continuous ratings of lesser values, and special restrictions, if any, must be clearly presented by the engine builder. Performance data provided shall include air borne and structure borne noise data.
9.3 Overload Ratings—If the prospective purchaser requires an overload rating, his request for proposal should clearly present the overload conditions desired to be permissible. Without such clarification, no overload rating is to be expected as a standard of the engine builder. If the engine is ordered and delivered with an overload rating, such rating shall be shown on the engine nameplate and on all appropriate engine documents.

10. Mechanical Efficiency of the Engine Assembly

10.1 The engine builder will identify in his proposal to the purchaser, the mechanical efficiency of the offered engine assembly as that term is used herein, with due allowance made in developing that number, for missing or non-engine driven power consuming parasitic loads, if any, as discussed in the foregoing herein. The engine builder shall later demonstrate in a timely report to the purchaser, based upon the test stand data and sophisticated recording of indicator cards, both applying to that specific engine, that the brake power as measured by the dynamometer is related to the indicated power by that efficiency factor (that is, brake power divided by efficiency in decimal form equals the indicated power).

11. Standard Conditions for Factory Test of Engines for Contractual Purposes

11.1 Standard for Heat Content of Diesel Fuel Used:

11.1.1 Fuel used shall conform to the engine manufacturer’s recommendations.

11.1.2 The reported specific fuel consumption of a liquid fuel engine, as determined by factory test, shall be corrected to reflect the lower calorific value (lower heat value/LHV) of that fuel when it is compared to a standard fuel of a lower calorific value of 42 000 kJ/kg (kilo-joules per kilogram), which lower calorific value may alternately be stated as 10 030 k-cal/kg (kilo-calories per kilogram). When related to practice common in the United States, note that the lower heat value (LHV) of the standard fuel will be found to be 18 057 Btu/lb, which implies an approximate high heat value (HHV) of 19 175 Btu/lb.

11.1.3 Correction formulae shall be as follows:

11.1.3.1 When working with units for LHV in Btu/lb, the specific fuel consumption reported to the purchaser shall be equal to the specific fuel consumption measured on the factory test stand after it is multiplied by a factor, the numerator of which is the LHV in Btu/lb of the fuel used, and the denominator of which is 18 057. Correction for other variations from standard conditions set forth later herein shall be applied to the specific fuel consumption figure derived as described immediately above.

11.1.3.2 When working with units for LHV in SI units of kJ/kg for the lower calorific value, the specific fuel consumption reported to the purchaser shall be equal to the specific fuel consumption measured on the factory test stand after it is multiplied by a factor, the numerator of which is the lower calorific value in kilo-joules per kilogram of the fuel used and the denominator of which is 42 000. Correction for other variations from standard conditions set forth later herein shall be applied to the specific fuel consumption figure derived as described immediately above.

11.2 Standard for Ambient Air Temperature at the Air Intake of the Engine:

11.2.1 The standard for comparison of output of engines in units of brake kilowatts (bkw) or brake horsepower (bhp) shall be 305.37K (32.22°C/90°F). ISO 3046/1 provides for treatment of test results obtained under diverse ambient air temperature conditions in paragraph 10.2 and elsewhere in that standard. Those methods are incorporated into this standard for adjustment of factory test results from actual ambient air temperature conditions to standard ambient air temperature conditions.

11.2.2 The maximum continuous brake horsepower (bhp) discussed in 4.1 preceding herein, and specific fuel consumption, discussed in Section 8 shall be guaranteed for circumstances wherein the temperatures of the air for combustion, as measured at the turbo-compressor inlet, are within a range identified to the purchaser by the engine builder in the proposal, offer to sell, or resulting contract, or a combination thereof.

11.3 Standard for Ambient Air Relative Humidity—Unless otherwise treated in the proposal or contract, the standard for ambient air relative humidity near the air intake of the engine shall be 30 % and shall be used as 0.3 as in ISO 3046/1, wherein provision is made for treatment of test results under diverse ambient air relative humidity conditions. Treatment of test results under diverse relative humidity conditions is provided by ISO 3046/1, page 4, paragraph 10. That method is incorporated into this guide for adjustment of factory test results from actual to standard relative humidity.

11.4 Standard for Ambient Air Total Barometric Pressure—Unless otherwise treated in the proposal or contract, the standard for ambient air total barometric pressure near the air intake of the engine shall be 95.665 kPa (28.25 Hg). Treatment of test results under diverse total barometric pressure conditions is provided by ISO 3046/1, page 4, paragraph 10. That method is incorporated into this guide for adjustment of factory test results from actual total barometric pressure conditions. Note that the tabular solutions in Annex E of ISO 3046/1 are applicable indirectly, if the standard total barometric pressure condition assumption varies from 100 KPa.

11.5 Standard for Temperature of Water to the Intercooler—Unless otherwise treated in the proposal or contract, the standard for temperature of water to the intercooler shall be 305.3K (32.22°C/90°F). ISO 3046/1 provides for treatment of test results obtained under diverse conditions of temperature of water to the intercooler. Such treatment is to be found in paragraph 10.2 and elsewhere in that standard. Those methods
are incorporated into this guide for adjustment of factory test results from actual intercooler water temperature conditions to standard conditions.

12. Turbocharger Performance

12.1 The engine builder shall submit to the purchaser, as a contract data item, a conventional compressor characteristic charge wherein the ordinate scale shall be pressure ratio and the abscissa scale shall be a mass flow parameter. There shall be plotted thereon points of pressure ratio as mass flow varies and the speed (r/min of the turbocharger assembly) parameter is constant. Superimposed on this, there shall be a family of curves or contours of compressor constant “total to total” isentropic efficiency (or alternately “total to static”).

12.1.1 The surge line, with sufficient margin, shall be clearly shown and the operating line, as matched to the engine for a propeller load curve, shall be shown. If this latter graphical superposition indicates a possible surge phenomenon for the proposed propulsion system, the purchaser and the engine builder shall consult together with respect to a solution, in light of the then-existing contract for purchase of the engines.

12.2 If surge conditions are possible, as a result of purchaser’s unique speed/power program for propeller revolutions per minute and propeller pitch incorporated into a control arrangement for a controllable and reversible pitch propeller, the engine builder shall provide an automatic combustion air bypass. Such bypass shall function as a result of joint measurement and integration of air header pressure and engine crankshaft revolutions per minute, such that turbo-compressor surge will be eliminated for a propulsion system, all components of which are in good order. The cost of such system modification shall be negotiated between the engine builder and the purchaser.

12.3 During factory test, surge tendencies will be investigated by sudden reduction of speed and power by percentage reductions and at a time rate to be selected by mutual agreement between the purchaser and the engine builder.

13. Special Fuel Tests

13.1 Medium speed marine propulsion diesel engines, purchased to burn blended or degraded fuels, are not usually subjected to factory test on such fuels before shipment.

13.2 If the purchaser desires such factory test, the requirement therefore and the cost therefore should be a negotiated item of the sales contract. The test agenda for such special test effort shall be negotiated between the engine builder and the purchaser.

13.3 While durability of the engine, if operated on blended or degraded fuels, cannot be demonstrated by a brief factory test, base data on performance characteristics of the engine, when operated on such fuels, should be established and provided to the purchaser as part of any factory test of the engine on such fuels.

13.4 The blended or degraded fuels to be used should be carefully specified and mutually agreed upon between the engine builder and the purchaser. The characteristics of the actual fuel supply used during such tests should be verified by laboratory analysis and provision of those data to the purchaser should be a contractual requirement.

13.5 Contract auxiliary engineered components may be used during such factory tests upon agreement between the engine builder and the purchaser. Such equipment, if used, shall be, as a contractual item, completely cleaned or rehabilitated, or both, before delivery to the purchaser.

13.6 Posttest inspection of the auxiliary or ancillary equipment used, if any, and of the engine assembly, shall be as agreed between the engine builder, the purchaser and the cognizant inspection society or classification society, or both.

13.7 Performance characteristics of the engine to be verified, when operating on blended or degraded fuels, should include, but are not necessarily limited to the following:

13.7.1 Emissions analysis to meet the specified requirements, if any, of the purchaser, and

13.7.2 Brake horse power developed without violation of the engine builder’s limits on such as, but not necessarily limited to, peak firing pressures; preturbine exhaust gas temperatures; injection pressures; air header temperatures; air header pressures; and turbocharger revolutions per minute; all for a spectrum of r/min and power levels.

14. Operating Parameters

14.1 The engine builder shall establish maximum or minimum readings for certain operating parameters for an engine of the model and number of cylinders under consideration, which will not be exceeded, or will be attained in the case of minimum values, when an engine in good operating condition and of that model and number of cylinders, is running and developing any point of power and revolutions per minute to be found within the acceptable operating area as delineated on the engine builder’s performance curves discussed in Section 4.

14.2 Such operating parameter maximums or minimums shall be regarded as contractual, whether embodied in the original contract or provided later as a constructive change to the contract, and shall include, but not necessarily be limited to, the following: brake mean effective pressure; mean piston speed/revolutions per minute of the engine crankshaft; combinations of brake mean effective pressure and revolutions per minute of the engine crankshaft as shown in the engine builder’s performance curves; maximum firing pressures as measured by the device and method recommended by the engine builder; individual cylinder exhaust gas temperature limits and the preturbine temperature limits for the mixture of all cylinder exhaust gases just upstream of the entrance to the turbocharger(s), if the engine is so equipped; maximum lubricating oil temperature in the lubricating oil header or an equivalent to a header; minimum lubricating oil pressure at a point in the system designated by the engine builder; temperature of the combustion air supply in the air inlet manifold; maximum viscosity of fuel at the suction of the fuel injection pump(s); minimum and maximum jacket water temperatures at a point in the system designated by the engine builder; and minimum jacket water pressure at a point in the system designated by the engine builder.
15. Keywords
15.1 brake horsepower of an engine; diesel; diesel engine; direct-reversible engine; engine assembly; engines; fuel map; fuel; internal combustion engine; main propulsion engine; map; marine engine; mass-elastic system; mechanical efficiency of an engine; medium speed diesel engine; parasitic loads; propulsion; surge line; torsional vibration; turbocharger; vibration analysis

APPENDIX
(Nonmandatory Information)

X1. Speed Ranges and MCR Information

X1.1 This guide was directed to be conceived and developed as the first of a group of guides, with follow-on guides to be developed subsequently. To proceed, main propulsion marine diesel engines were divided into classes defined by crankshaft revolutions per minute speed ranges as follows:

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<th>Speed Range</th>
<th>RPM Range</th>
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<tr>
<td>Very low speed</td>
<td>80 to 120 r/min</td>
</tr>
<tr>
<td>Low speed</td>
<td>150 to 360 r/min</td>
</tr>
<tr>
<td>Medium speed</td>
<td>400 to 600 r/min</td>
</tr>
<tr>
<td>High speed</td>
<td>700 to 900 r/min</td>
</tr>
<tr>
<td>Very high speed</td>
<td>1200 r/min and higher</td>
</tr>
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</table>

The end points between the defined speed ranges are deliberate and represent a strong influence by 60-Hz alternating current electric power generator design characteristics.

X1.2 With respect to MCRs, it must be kept in mind that the power required to develop a given vessel speed through the water, will generally tend to increase over the life of the vessel and will increase markedly as a result of bottom fouling between drydock and bottom cleaning and painting intervals. Therefore, it is not prudent in the general case to install a diesel engine as a main propulsion engine in a situation in which the screw propeller or other thrust-producing device requires the engine to operate at the MCR, when the vessel is new and the hull is clean, to achieve the speed through the water required for the vessel to be economically successful in its proposed trade. System analysis by a competent marine engineer, with respect to propeller, vessel speed, and engine-installed power, should be arranged by the purchaser.
1. Scope

1.1 This specification covers manually operated fueling hose reels for use with collapsible and noncollapsible hose.

1.2 The values stated in inch-pound units are to be regarded as standard. The SI units given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the test methods portion, Section 12 of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
   - B 148 Specification for Aluminum-Bronze Sand Castings
   - D 3006 Specification for Polyethylene Plastic Pressure-Sensitive Electrical Insulating Tape
   - D 3951 Practice for Commercial Packaging

2.2 Military Specifications:
   - MIL-S-901 Shock Test, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
   - MIL-T-16366 Terminals, Electric Lug and Conductor Splices, Crimp Style
   - MIL-H-17902 Hose, End Fittings and Hose Assemblies, Synthetic Rubber, Aircraft Fuels
   - MIL-F-20042 Flanges, Pipe and Bulkhead, Bronze (Silver Brazing)
   - MIL-P-24441 Epoxy-Polyamide Primer

2.3 Military Standard:
   - MIL-STD-130 Identification Marking of U.S. Military Property

3. Classification

3.1 Fueling hose reels shall be of one of the following types as specified:
   - 3.1.1 Type 1—for 150 ft (46 m) of collapsible 2\(\frac{1}{2}\)-in. (65-mm) hose.
   - 3.1.2 Type 2—for 150 ft (46 m) of noncollapsible 1\(\frac{1}{2}\)-in. (38-mm) hose or 100 ft (30 m) of noncollapsible 2-in. (50-mm) hose.
   - 3.1.3 Type 3—for 150 ft (46 m) of noncollapsible 1\(\frac{1}{2}\)-in. (38-mm) hose or for 150 ft (46 m) of collapsible 2\(\frac{1}{2}\)-in. (65-mm) hose.
   - 3.1.4 Type 4—Capacity as specified by purchaser.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:
   - 4.1.1 Title, number, and year of issue of this specification.
   - 4.1.2 Type of hose reel including hose size and type (see 3.1), length of hose for Type 4).
   - 4.1.3 Whether right- or left-hand reels are required (see 6.5).
   - 4.1.4 Flange inlet thickness and bolt hole dimensions (see 6.7).
   - 4.1.5 Drawings required (see 9.1).
   - 4.1.6 The number of samples to be inspected and tested (see 11.2).
   - 4.1.7 Certification, if required (see 15.1).
   - 4.1.8 Test report, if required (see 15.1).
   - 4.1.9 Applicability of supplementary requirements.

5. Materials and Manufacture

5.1 Except as otherwise specified herein, the hose reels shall be constructed of aluminum, aluminum bronze, or other suitable nonsparking materials. All fittings conveying aromatic fuels through the hose reel shall be made of aluminum bronze in accordance with Specification B 148, copper alloy UNS No. C95300. To prevent deterioration in sea atmosphere, aluminum parts should not contact brass or bronze; however, where such aluminum parts come in contact with brass or bronze, they
shall be protected by adhesive-backed insulating tape, Specification D 3006. All aluminum parts shall be given a coat of epoxy-polyamide primer.

6. Construction

6.1 Reel and Drum Assembly—The hose reel shall be of a durable, rigid construction, as light in weight and compact as practicable. The drum assembly (drum, reel sides, and its reinforcements) shall withstand the hose pull without distortion or collapse and shall be capable of withstanding some sideways hose pull without undue distortions. The construction of the completed drum assembly shall be such that disassembly can be readily accomplished with standard tools. When bolted down to a true flat surface, the shaft and rotating seal centerlines shall be in true alignment and the drum assembly shall turn without binding under a rim pull not to exceed 7 lb (198 kg) with the reel unpressurized. Both ends of the drum shaft shall be supported on ball or roller bearings that shall have provision for easy lubrication. Reels shall be designed so that all bearings, and other corrodible parts, are adequately protected from the weather. Provision shall be made for lubrication of working parts such as bearings or other mating surfaces, and all such parts shall be lubricated before delivery with a lubricant soluble in aromatic fuels. Bearing seals shall be such that the pressure caused by forced lubrication will not bind the shaft.

6.2 Reel Drum—The reel drum may have either smoothly formed flat sides or suitable spoke ribs, so formed as not to damage the hose. The rims of the drum shall provide a good grip for hand rewind.

6.3 Holding Brake—Reels shall be provided with a holding brake to lock the reel in any position.

6.4 Nozzle Clamp—The reel shall be fitted with a device for clamping the hose nozzle securely to the reel to prevent unwinding of the hose and damage to the nozzle.

6.5 Reel Hub Discharge—The reel hub discharge shall be angled to provide a smooth tangential contact of the hose with the reel drum as shown on Fig. 1 and Fig. 2, so that the hose will not kink at the discharge connection. The hub discharge fitting and adapter shall be in accordance with Fig. 2 and Fig. 3 for Types 1, 2, and 3, respectively. Reels shall be right- or left-hand operation and top or bottom wind, as specified. A right-hand, top-wind reel is defined as one that, when looking into the flanged adapter on the discharge fitting when it is at the top of the drum, has its inlet connection on the right-hand side. (Note that a top-wind, right-hand reel and a bottom-wind, left-hand reel are identical.) It shall be possible by turning the discharge fitting around, or by other simple means, to enable the hose to unreel from the bottom of the reel drum to either side of the reel (that is, to make the reel either right hand or left hand) without rotating the reel drum.

6.6 Aromatic Fuels Tight Rotating Joint—The reel shall have an aromatic fuels tight rotating joint between reel inlet
connection and the rotating hub on the reel drum. The rotating joint shall not bind under loading (shall be supported to prevent a bending load being applied), shall have provision for lubrication of moving parts, and shall be capable of easy disassembly for maintenance purposes. The rotating joint shall be tight under the pressure specified in 7.1.

6.7 Inlet Connection—The reel inlet connection shall be flanged, the flange being part of the rotating swivel joint. The flange thickness and bolt hole drilling shall be as specified in the contract or purchase order.

7. Performance Requirements

7.1 Fluid Handling—Reels shall be capable of passing 300 gal/min (0.0189 m³/s) of aviation fuel at a pressure of 150 psi (1.03 MPa) and shall withstand a static fuel pressure of 225 psi (1.55 MPa) without leakage or other signs of weakness. Restrictions and turbulence through the reel shall be kept to a minimum. For this purpose, the fluid path shall be of the 3½-in. (90-mm) size (including rotating swivel joint) and shall use long sweep elbows. The complete fluid-handling section of the reel (that is, from inlet flange to flanged adapter) shall be capable of being removed as a unit without disassembly of the drum or reel sides.

7.2 Reel Hose Capacity—Reels shall be capable of containing lengths of hose, as required, for Types 1, 2, 3, or 4. The hose used shall be either collapsible or noncollapsible as specified.

7.3 Temperature—The reels and the lubricant used shall be capable of satisfactory operation within the range of temperatures from −20 to +120°F (−29 to +49°C).

8. Dimensions, Mass, and Permissible Variations

8.1 The drum diameter shall not be less than the minimum bending diameter of the hose. The general outline and base mounting dimensions and mass shall be in accordance with Fig. 1.

9. Drawings

9.1 When specified in the contract or purchase order, detail assembly drawings shall be provided.

10. Workmanship, Finish and Appearance

10.1 The reel and all parts shall be free of imperfections that may impair serviceability.

11. Sampling

11.1 Lot—For quality conformance, a lot shall consist of all reels of the same type, made at the same factory, of the same materials, of the same construction, and offered for delivery at the same time.

11.2 Sampling for Quality Conformance—Reel samples shall be selected at random from each lot offered for delivery. The number of samples to be tested or inspected shall be in accordance with Table 1, unless otherwise agreed between the
purchaser and the supplier and the quantity shall be specified in the contract or purchase order.

12. Test Methods

12.1 Hydrostatic Test—Hydrostatically test the fluid-carrying portion of the hose reel to 225 psi (1.55 MPa) and hold this pressure for 5 min to test for strength and porosity. Also pressure test the reel by kerosene or synthetic test fluid (solvent) to 120 psi (827 kPa) for tightness. Hold this pressure for 5 min.

12.2 Operating Test—Load-assembled reels selected in accordance with 11.2 with hose and operate by hand to test all functions, fits, clearances, and adjustments.

13. Inspection

13.1 Examination—Sample reels selected in accordance with 11.2 shall be examined to determine conformance with all the requirements of this specification, not involving tests.

14. Rejection

14.1 Defects—Any defective reels in the sample shall not be offered for delivery. If the number of defective reels in any sample exceeds the acceptance number (see Table 1), this shall be cause for rejection of the entire lot.

14.2 Leakage—The reel shall show no leakage or any other signs of weakness after the performance of the tests specified in 12.1 and 12.2.

15. Certification

15.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as required by this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Product Marking

16.1 Each hose reel shall be marked with this ASTM standard number, type of hose reel, reel hose capacity, type of hose, and size of hose.
17. Packaging and Package Marking

17.1 Packaging and package marking shall be in accordance with Practice D 3951.


18.1 Responsibility for Inspection—The supplier is responsible for the performance of all test and inspection requirements as specified herein. The supplier may use his own facilities or a commercial laboratory. The purchaser reserves the right to perform any of the inspections or tests set forth in the specification where such tests or inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

19. Keywords

19.1 fueling hose reel; hose reel; reel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are applicable to Department of Defense procurements and shall apply only when specified by the purchaser in the contract or purchase order:

S1. Referenced Documents


S1.2 Military Standard—MIL-STD-130.

S2. Construction

S2.1 Discharge Fitting—Unless otherwise specified in the contract or purchase order, the discharge fitting shall have an electrical contact at the center to bear against a similar contact button in the hose. From this contact on the discharge fitting, there shall be a continuous electrical path through the center of the hose reel to a terminal on the stationary part of the reel at the inlet connection (see Fig. 1 and Fig. 2). The electrical circuit through the reel shall be electrically insulated from the reel.

S2.2 Electrical Connections—The contact spider shown (see Fig. 2 and Fig. 3) shall be molded nylon, and the assembly shall be in accordance with requirements of MIL-H-17902. The stationary terminal shall be in accordance with MIL-T-16366. Electrical contact button on the discharge fitting shall be as shown on Fig. 2 and Fig. 3.

S2.3 Hose—The fueling hose to be used with these reels will be in accordance with MIL-H-17902.

S2.4 Inlet Connection—Unless otherwise specified in the contract or purchase order, the flange thickness and bolt hole drilling shall be in accordance with Class 250 of MIL-F-20042. The bolt holes shall straddle the vertical centerline of the flange.

S2.5 Primer—All steel and aluminum parts shall be given a coat of epoxy-polyamide primer, see MIL-P-24441.

S3. Shock Tests

S3.1 Shock Tests—The high impact (HI) shock tests shall be Grade A, Class 1, Type A tests in accordance with MIL-S-901. The reel shall be completely assembled (including hose) and shall be mounted on the shock machine in a manner simulating a typical shipboard installation. The number of blows shall be as specified in MIL-S-901.

S3.2 Examination After Shock Tests—Upon completion of the shock test, the equipment shall be carefully examined to determine the extent of any damage to the mechanical components. Examination of the reels shall determine the following:

S3.2.1 The hose shall be unreeled completely and then rolled back on the reel at least five times. Any undue noise or difficulty in operation shall be investigated and the cause determined.

S3.2.2 Any unbalance shall be measured and shall not exceed twice the amplitude obtained before shock.

S3.2.3 A conductivity check shall be made to ensure that the electrical circuit through the reel is intact.

S3.2.4 The fluid-handling section of the reel (between inlet flange and discharge connection) shall be given a hydrostatic test to 225 psi (1.55 MPa) for strength and porosity and a kerosene or test fluid (solvent) test to 60 psi (413 kPa) and 120 psi (827 kPa) for tightness without showing any signs of leakage or other weakness.

S3.2.5 The reels shall be disassembled following the examination after shock tests specified and examined thoroughly for damage. The effects of the shock tests and subsequent check tests on the structure shall be carefully observed and recorded.

S3.3 Failure to Pass Shock Tests—The hose reel shall be considered to have failed to pass the shock tests in the event of the following:

S3.3.1 Breakage of any parts including mounting bolts.

S3.3.2 Appreciable distortion or dislocation of any parts, including mounting feet, bearings.

S3.3.3 Excessive unbalance determined as specified in S3.2.

S3.3.4 Failure to pass the hydrostatic or electrical conductivity tests.

S4. Product Marking

S4.1 Reels shall be marked in accordance with MIL-STD-130. The size of the hose to be used shall be stamped on each reel.

S5. Sampling

S5.1 In addition to the sampling requirements of the basic specification, Table 1 applies for number of samples and rejection level. If the number of defective reels in any sample exceeds the acceptance number, the lots shall be rejected.
Standard Specification for
Pneumatic Rotary Descaling Machines

This standard is issued under the fixed designation F 1348/F1348M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers requirements for pneumatic rotary descaling machines for removal of paint, rust, scale, nonskid deck covering, and other coatings from steel and aluminum structures. These portable machines are intended for use in a marine environment, subject to salt air and spray during use and high humidity during storage.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following precautionary statement pertains to the test method portion only, Section 12, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given in 17.2.1.

2. Referenced Documents

2.1 ASTM Standards:

B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel
F 1166 Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities

2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 Federal Specifications:

PPP-B-566 Boxes, Folding, Paperboard

3. Classification

3.1 Descaling machines are available in two types and two classes, as follows:

3.1.1 Type 1, Hand-Held:

3.1.1.1 Class A—inch-pound design, and
3.1.1.2 Class B—SI metric design.

3.1.2 Type 2, Deck-Supported:

3.1.2.1 Class A—inch-pound design, and
3.1.2.2 Class B—SI metric design.

3.2 Hubs for use with descaling machines are available in four classes, as follows:

3.2.1 Class A—Nonmetallic, nonwoven, noncontaminating,
3.2.2 Class B—Peening hub for aluminum surfaces,
3.2.3 Class C—Metallic hammer type for steel surfaces, and
3.2.4 Class D—Metallic cutter type for steel surfaces.

4. Ordering Information

4.1 Orders for material under this specification shall include the following:

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<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

<sup>2</sup> Annual Book of ASTM Standards, Vol 02.02.

<sup>3</sup> Annual Book of ASTM Standards, Vol 06.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.07.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>6</sup> Available from American Bureau of Shipping, ABS Plaza, 16855 Northchase Dr., Houston, TX 77060.

<sup>7</sup> Available from Uniform Classification Committee Agent, Tariff Publication Officer, Room 1106, 222 S. Riverside Plaza, Chicago, IL 60606.
4.1.1 Title, number, and date of this specification,
4.1.2 Quantity,
4.1.3 Type and class required (see Section 3),
4.1.4 Test and inspection certification requirements, if applicable (see Section 15),
4.1.5 Test report requirements (see Section 15),
4.1.6 Technical manual requirements (see Section 16),
4.1.7 Special marking required (see 18.3),
4.1.8 Level of preservation, packaging, packing, and marking required (see Section 17 and Supplementary Requirements), and
4.1.9 Lubrication requirements of Supplementary Requirements, if applicable (see Section S3).

5. Materials and Manufacture

5.1 Asbestos and Cadmium:
5.1.1 Material used in the machines, or in any components, accessories, repair parts, tools, and packing and packaging shall be free of asbestos and cadmium.
5.2 Metal Parts—Metal parts shall be corrosion resistant or treated to resist corrosion.

6. Mechanical Properties

6.1 The machines shall be powered by an air motor and shall accept each of the rotary hubs (see 6.9).
6.1.1 *Type 1*—The Type 1 machine shall be a hand-held unit having a minimum of two handles, one of which shall house the trigger mechanism. The trigger mechanism shall be of the spring-loaded “dead man” type and shall immediately shut off air flow to the motor when released. The arrangement of the handles and trigger mechanism shall permit right- or left-handed operation with equal ease. The direction of rotation of the hubs shall tend to propel the machine in the forward direction, away from the operator. The Type 1 machine shall remove coatings to within 1/4 in. [6 mm] of bulkheads, coamings, decks, and other immovable objects.
6.1.2 *Type 2*—The Type 2 machine shall be a deck supported unit with a T-shaped operating handle. The operating handle shall be adjustable for height, rigid and strong enough to operate the machine without bending, and long enough to allow any operator with the percentile body dimensions specified herein (see 6.2) to operate the machine while walking behind it in a natural walking position. The air hose connection and trigger mechanism shall be located on the T-handle. The trigger mechanism shall be of the spring-loaded “dead man” type and shall immediately shut off air flow to the motor when released. The handle shall detach or be adjustable to and lockable in the vertical position for storage. The machine shall be provided with at least two wheels used to move the machine. With the handle, air hose and each of the abrasive hubs attached, the machine shall sit level on the deck with the abrasive hubs in contact with the deck and not interfere with deck coating removal process. The machine shall easily propel itself or be propelled by the operator across the deck without overstressing the operator (see 6.2). The Type 2 machine shall remove deck coating to within 1 1/2 in. [40 mm] of the bulkheads, coamings, and other immovable objects.

6.2 Human Engineering—The machines shall be in accordance with the human engineering criteria of Practice F 1166 except where such requirements conflict with the requirements of this specification. The machines shall incorporate the maintainability requirements of Practice F 1166 and shall permit safe and efficient performance of operation and maintenance by the fifth percentile female to the ninety-fifth percentile male, as defined in Practice F 1166. Clearance shall be provided around each component, part or control so that an individual with aforementioned percentile body dimensions and physical capabilities can safely operate, maintain, remove, or replace any item using normally available tools and test equipment. The controls required for operation and maintenance shall be in accordance with Practice F 1166 and shall not require operator forces to exceed the strength limitations listed therein.

6.3 Interchangeability—Component parts and assemblies peculiar to each type and class of machine from any one manufacturer shall be fully interchangeable. Such interchangeability shall not require any alterations or modifications.

6.4 Dimensions and Weight—The machines, fully assembled with guards; debris collector attachment (less hoses and collection container); and with operating handles (Type 2) locked in its operating position; fully lubricated and ready in all aspects for operation (less air hose and filter, evaporator and lubricator attachments) shall not exceed the maximum dimensions and weight shown in Table 1.

6.5 Air Motor—The machines shall be driven by air motors that operate on the minimum air supplies as shown in Table 2.

6.6 Guards—Machines of both Type 1 and Type 2 shall be provided with guards that protect the operator from inadvertent contact with moving parts and prevent uncontrolled scattering of chips or scale removed by the machine. These guards shall not interfere with the performance of the machine throughout the machine’s useful life, unduly decrease any of the hub’s physical dimensions or wear, or interfere with changing of the hubs. The guards/rotary hub containment shall be constructed to accommodate a debris collection system.

6.7 Air Connections—Air connections for both Type 1 and Type 2 machines shall be of the quick disconnect type. The locations of the air connection shall be such that the hose does not interfere with operation of the machine or the operator. The inside diameter of the connections shall be in accordance with Table 3.

6.8 Lubrication—Lubrication fittings shall be installed so that lubrication can be accomplished without disassembly of the machine (see 6.2). Lubrication materials shall be high-temperature lubricating oil or high-performance grease.

6.9 Hubs:

6.9.1 Hubs for each type and class of machine shall clean a path of width not less than that shown in Table 4. Hubs for each type, class, and manufacture of machine shall be interchangeable with hubs of any other machine of the same type, class,
and manufacture, using only the normally available tools (see 8.1.2) for the interchange.

6.9.2 Hubs shall be of the following classes, classified by intended composition, function, and service life, as follows:

6.9.2.1 Class A Hub—The Class A hub shall be nonmetallic, nonwoven, noncontaminating, and shall remove paint, rust, or scale. The Class A hub shall feather the edge of a painted surface in a smooth taper from the painted aluminum surface to bare metal, and shall not remove, erode, or groove metal surfaces. The Class A hub shall have a minimum service life of 8 h.

6.9.2.2 Class B Hub—The Class B hub shall remove paint, rust, or scale and shall peen the aluminum surface to a profile of 1.0 to 3.0 mils [0.0025 to 0.0076 mm]. The Class B hub shall have a minimum service life of 50 h.

6.9.2.3 Class C Hub—The Class C hub shall be a metallic hammer type assembly and shall remove paint and nonskid covering on steel surfaces. The Class C hub shall operate over protrusions or obstructions on the deck surface, such as bolts or padeyes, up to a height of 1 in. [25 mm], without damage to the hub or machine. The Class C hub shall have a minimum service life of 100 h.

6.9.2.4 Class D Hub—The Class D hub shall be a metallic type cutter assembly that removes paint, rust, scale, and nonskid deck coverings on steel surfaces. The Class D hub shall have a minimum service life of 30 h.

7. Performance Requirements

7.1 Removal Rate—The minimum removal rate when tested in accordance with Section 12 shall be as specified in Table 5 and Table 6.

7.1.1 Type 1 Machine—See Table 5.

7.1.2 Type 2 Machine—See Table 6.

7.2 Stability:

7.2.1 Type 1 Machine—The assembled Type 1 machine shall operate at any angle from the horizontal to vertical (including the overhead) without loss of power or descaling efficiency.

7.2.2 Type 2 Machine—The assembled Type 2 machine shall operate without loss of power and descaling efficiency and without tipping when inclined at an angle of 15° from the horizontal in any direction.

8. Attachments

8.1 The machine shall be furnished in kit form, with each kit containing the following items besides the basic machine:

8.1.1 One Class A hub,
8.1.2 One Class B hub,
8.1.3 One Class C hub,
8.1.4 One Class D hub,
8.1.5 One air hose with fittings,
8.1.6 One hub-changing tool (or tool set),
8.1.7 One debris collector,
8.1.8 One carrying case, and
8.1.9 One in-line filter/evaporator/lubricator.

8.1.10 Air Hose—Air hoses shall be ¾ in. [10 mm] for Type 1 machine and ½ in. [19 mm] for Type 2 machine with quick-disconnect connections and an air shutoff valve that shall immediately shut off the air when the hose is disconnected. The hose for the Type 1 machine shall be 50 ft [15 m] long and the hose for the Type 2 machine shall be 100 ft [30 m] long.

8.1.11 Hub Changing Tool—A standard commercially available tool for changing hubs shall be provided. The tools shall not be unique to a specific supplier.

8.1.12 Carrying Case—The carrying cases for Type 1 and Type 2 machines shall be corrosion-resistant, fire-resistant, high-impact material, strong and rigid enough to transport the machine and its accessories. The carrying case shall rigidly hold all accessories with the exception of hoses, without deformation or breakage, and shall be less than 24 in. [610 mm] wide. The carrying case shall also hold the machine’s handle when the handle is disconnected.

8.1.13 Debris Collector—Both Type 1 and Type 2 machines shall be capable of attaching a debris collecting device that will collect a minimum of 95 % of the debris created.

8.1.14 In-Line Filter/Evaporator/Lubricator—A filter to remove air system debris, an evaporator to remove moisture, and a lubricator to continually lubricate the machine or a combination unit shall be installed to ensure satisfactory long-term...
use in a marine environment. These units shall not hinder the operator’s ability to handle and use the machine.

9. Number of Tests

9.1 A first unit shall satisfactorily pass the tests in Section 12 before production units are offered for delivery.

10. Specimen Preparation

10.1 Test Plates—Steel test plates shall be in accordance with the American Bureau of Shipping (ABS) Rules for Building and Classing Steel Vessels. Aluminum test plates shall be in accordance with Specification B 209, Alloy 5086. Test plates shall be at least \( \frac{1}{2} \) in. [6 mm] thick. Area of plates used in performance tests shall be at least equal to the area that would be cleaned in 10 min at the minimum hourly removal rate for the machine and hub being tested.

10.2 Test Surface Preparation:

10.2.1 Test plates shall be prepared for the performance tests as specified herein. Coatings shall be prepared for application in accordance with manufacturer’s instructions.

10.2.1.1 Painted Surfaces—The steel or aluminum surface shall be cleaned to a uniform white appearance with a minimum surface profile of 1.0 to 3.0 mils [0.025 to 0.075 mm]. The surface shall be dry and free of all contaminants. Two coats of an epoxy-polyamide primer followed by two coats of epoxy paint shall be applied, each coat approximately 3 mils [0.075 mm] thick. Minimum time between coats and between application of last coat and commencement of test shall be 24 h each.

10.2.1.2 Rusted Steel Surfaces—The steel surface shall be wet and exposed to air until it exhibits a complete, uniform coating of rust. A saline solution may be applied to speed rusting. The rusted surface shall be allowed to air dry before testing.

10.2.1.3 Surface with Nonskid Coating—The surface shall be cleaned to a uniform white appearance with a minimum surface profile of 1.0 to 3.0 mils [0.025 to 0.075 mm]. The surface shall be dry and free of all contaminants. One coat of an epoxy-polyamide primer approximately 3 mils [0.075 mm] thick and one coat of a nonskid coating compound shall be evenly applied. The nonskid compound shall be a two part synthetic resin compound, consisting of the basic resin plus aggregate and hardener. The nonskid after curing shall have a minimum average thickness of 30 mils [0.75 mm]. Minimum time between coats and between application and drying/curing of last coat and commencement of test shall be 24 h.

11. Responsibility for Tests and Inspections

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements. Each party has the right to witness tests performed by the other party.

12. Test Methods

12.1 Service Life Test—Conduct service life tests on an uncoated steel test plate (see 11.1). Operate the machine and each hub in full contact with the test plate for the minimum service life specified herein for the particular hub being tested. The test may be continuous or may consist of shorter time periods adding up to the applicable service life. Breaks between the shorter test periods are limited to 1 h followed by 1 h or more of operation (simulation of daily usage). Fracture, bending, or other failures affecting useability of any component of the machine or hub constitutes a defect. The service life test precedes the performance tests for each hub.

12.2 Performance Tests:

12.2.1 Test each hub on the test surfaces required in Table 7. Use the machine for 10 min. Measure the area of the surface that is cleaned to bare metal in 10 min and multiply by six to determine the hourly removal rate. Failure to attain an hourly removal rate at least equal to the minimum removal rate stated in Section 7 constitutes a defect.

12.2.1.1 Class A Hub—After each performance test with the Class A hub, examine the metal surface for scoring, gouging, or erosion of metal. Presence of any of these conditions constitutes a defect.

12.2.1.2 Class B Hub—After each performance test with the Class B hub, test the metal surface in accordance with Test Methods D 4417 to determine its surface profile. Failure to produce a surface profile between 1.0 to 3.0 mils [0.0025 to 0.0076 mm] constitutes a defect.

12.3 Stability—Test the Type 1 machine on horizontal (including the overhead) and vertical surfaces at no load and full load. Conduct stability operation test on the Type 2 machine inclined at an angle of 15° in any direction from the normal horizontal position and at both no load and full load. For the Type 2 machine, loss of power or tipping constitutes a defect.

12.4 Precision and Bias—No statement is made about either the precision or bias of these test methods since the result merely states whether there is conformance to specified operating requirements.

13. Inspection

13.1 Visual Inspection—A visual inspection shall be made of each machine for the following defects:

13.1.1 Any part or component not as specified, missing, or damaged,

13.1.2 Hubs not interchangeable, and

13.1.3 Air hose failing to connect to machine.

### Table 7: Required Performance Tests

<table>
<thead>
<tr>
<th>Surface</th>
<th>Class A Hub</th>
<th>Class B Hub</th>
<th>Class C Hub</th>
<th>Class D Hub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painted steel</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Painted aluminum</td>
<td>X</td>
<td>X</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Rusted steel</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Steel with nonskid</td>
<td>. . .</td>
<td>. . .</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
14. Rejection

14.1 Any defect shall be cause for rejection.

15. Certification

15.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Technical Manuals

16.1 Unless otherwise specified in the purchase order or contract (see 4.1.6), the manufacturer’s standard operation and maintenance manual shall be provided with each unit. As a minimum, the technical manual shall contain information regarding unpacking, inspection, assembly, operation, controls, lubrication, routine maintenance, replacement of parts, and a parts listing.

17. Product Marking and Labeling

17.1 Identification Marking—Each machine shall bear a manufacturer’s nameplate securely attached to the outside of the housing citing the manufacturer’s name, contract number, and model number of the machine.

17.2 Warning Label:

17.2.1 The machine shall be provided with a warning label, firmly affixed in a prominent location. The characters shall be not less than \(\frac{3}{8}\) in. \([9.5\, \text{mm}]\) high and in accordance with Practice F 1166. The label shall state:

WARNING

DO NOT OPERATE WITHOUT HEARING
AND EYE PROTECTION
EAR AND EYE DAMAGE MAY RESULT

17.2.2 The word “WARNING” shall be printed in yellow on a black background. The message below it shall consist of black letters on a yellow background. Similar warning or caution label plates shall be affixed for other situations that would create a personnel hazard or equipment damage.

18. Packaging and Package Marking

18.1 Preservation and Packaging—Preservation and packaging shall provide adequate protection against corrosion, deterioration, and physical damage during shipment and, unless otherwise specified, may conform to the supplier’s commercial practice when such meets these requirements. Each machine shall be complete, fully lubricated, and ready to operate upon delivery (some assembly is allowed). Technical manuals furnished with basic equipment shall be packaged in sealed, waterproof wrapping.

18.2 Packing—Packing shall be accomplished in a manner that will ensure acceptance by common carrier at the lowest rate and will afford protection against physical or mechanical damage during shipment. The shipping containers or method of packing shall conform to the Uniform Freight Classification Rules and Regulations or other carrier regulations as applicable to the mode of transportation and unless otherwise specified, may conform to the supplier’s commercial practice when such meet these requirements.

18.3 Marking—Unless otherwise specified (see 4.1.7), shipment marking information shall be provided on interior packages and exterior shipping containers as follows:

18.3.1 For Commercial Procurements—in accordance with the contractor’s commercial practice,

18.3.2 For U.S. Government Agencies, Except Military—in accordance with Fed. Std. No. 123,

18.3.3 For U.S. Military Agencies—in accordance with MIL-STD-129.

19. Keywords

19.1 air hose; air motor; descaling; hose; air; hub; machine; pneumatic

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Referenced Documents

S1.1 Military Standard—MIL-STD-147.


S1.3 Federal Specifications—PPP-B-566, PPP-B-601, PPP-B-621, PPP-B-636, PPP-B-640, and PPP-B-676.

S2. Packaging

S2.1 Disassembly and Matchmarking—Item disassembly shall be the minimum necessary to make accessible for cleaning, drying, and preservation of machined and critical surfaces. Removal of items or projecting parts which will facilitate protection of the equipment or item from damage, pilferage, loss, or reduce package volume, is permitted where such removal will not affect permanent settings or alignments, and where the removed items can be readily reassembled at the installation site without the need for special tools. Removed items shall be matchmarked to facilitate reassembly. Removed items shall be tagged and marked with the tags attached to each mating item.
S2.2 Carrying Case—Each machine shall be packaged in its carrying case such that chaffing or contact of machine parts is prohibited. All accessories shall be packaged in packages conforming to MIL-B-117, Type 1, Class C, Style 2, and packed in a carrying case.

S2.3 Packaging Materials:

S2.3.1 Unit Containers—Unit containers shall conform to any one of the following specifications. Selection of the container and options provided in the applicable container specification shall be at the suppliers option:

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-566</td>
<td>Box, paperboard, folding</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>Box, fiberboard</td>
</tr>
<tr>
<td>PPP-B-676</td>
<td>Box, paperboard, setup</td>
</tr>
</tbody>
</table>

S2.3.2 Box closure shall be in accordance with the applicable box specification or appendix thereto. Closure, waterproofing, and reinforcing as applicable for fiberboard boxes, when selected, shall be as follows: domestic grade in accordance with Method 1 using pressure sensitive, reinforced, strippable tape; weather-resistant grade in accordance with Method 5.

S2.4 Storage Box—Each carrying case shall be placed in a container as specified in S2.3.1. Fiberboard pads shall be provided to obtain a snug fit and to protect all projecting items (hardware, handle) from damage during handling, shipment and storage.

S2.5 Packing—Packing shall be Level A, B, or C as specified.

S2.5.1 Levels A and B—Machines shall be packed in containers as specified (see S2.5.1.1). When the unit container selected is of the weather-resistant grade, no further overpacking is required.

S2.5.1.1 Containers—Containers shall be in accordance with any of the specifications listed in Table S2.1. Selection of the container and options provided in the applicable specification shall be at the suppliers option.

S2.5.1.2 Closure, Reinforcing, and Waterproofing—Shipping containers shall be closed, strapped, or banded in accordance with the applicable container specification or appendix thereto. For Level A packing, fiberboard boxes shall be reinforced with pressure-sensitive reinforced, filament tape, or nonmetallic banding as specified in the appendix, to the applicable fiberboard box specification instead of steel strapping.

S2.5.2 Level C—Products shall be packed in containers at the lowest applicable level acceptable to the common carrier and that will ensure safe delivery of contents at the Naval receiving activity in a satisfactory condition for use. Containers, packing, and method of shipment shall comply with the ABS Uniform Freight Classification Rules and Regulations or other carrier as applicable to the mode of transportation.

S2.6 Palletized Unit Loads—When applicable, products packaged as specified shall be palletized in accordance with MIL-STD-147.

S2.7 Hose—Hose shall be prepared for shipment in accordance with MIL-P-775 for the levels of protection specified.

S3. Lubricants

S3.1 All lubricants shall be in accordance with MIL-L-17331 or DOD-G-24508.

S4. Inspection of Packaging

S4.1 Sample packs and the inspection of preservation, packing, and marking for shipment and storage shall be in accordance with Sections 16 and 2 and the documents specified herein.

---

TABLE S2.1 Container Selection

<table>
<thead>
<tr>
<th>Specification</th>
<th>Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP-B-601</td>
<td>boxes, wood cleated plywood</td>
</tr>
<tr>
<td>PPP-B-621</td>
<td>boxes, wood, nailed and lock-corner</td>
</tr>
<tr>
<td>PPP-B-636</td>
<td>boxes, shipping, fiberboard</td>
</tr>
<tr>
<td>PPP-B-640</td>
<td>boxes, fiberboard, corrugated, triple-wall</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packing Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level A</td>
</tr>
<tr>
<td>Level B</td>
</tr>
<tr>
<td>(Style, Type, or Class)</td>
</tr>
<tr>
<td>overseas type</td>
</tr>
<tr>
<td>domestic type</td>
</tr>
<tr>
<td>Class 2</td>
</tr>
<tr>
<td>overseas</td>
</tr>
<tr>
<td>Class 1</td>
</tr>
<tr>
<td>domestic</td>
</tr>
<tr>
<td>Class 2</td>
</tr>
<tr>
<td>weather resistant</td>
</tr>
<tr>
<td>Class 1</td>
</tr>
</tbody>
</table>

---

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Standard Specification for
Pressure-Reducing Valves for Water Systems, Shipboard

This standard is issued under the fixed designation F 1370; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers self-contained, globe style, pressure-reducing valves for use in water systems of shipboard installations. These valves are limited to discharge pressure settings of 200 psig (1379 kPa) and below.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the tests portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
   A 125 Specification for Steel Springs, Helical, Heat Treated
   A 193 Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
   A 194 Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
   A 231 Specification for Chromium-Vanadium Alloy Steel Spring Wire
   A 276 Specification for Stainless and Heat-Resisting Steel Bars and Shapes
   A 313 Specification for Stainless and Heat-Resisting Steel Spring Wire
   A 689 Specification for Carbon and Alloy Steel Bars for Springs
   B 21 Specification for Naval Brass, Rod, Bar, and Shapes
   B 26 Specification for Aluminum-Alloy Sand Castings
   B 61 Specification for Steam or Valve Bronze Castings
   B 62 Specification for Composition Bronze or Ounce Metal Castings
   B 148 Specification for Aluminum-Bronze Sand Castings
   B 150 Specification for Aluminum Bronze Rod, Bar, and Shapes
   B 637 Specification for Precipitation Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service
   B 689 Specification for Electroplated Engineering Nickel Coatings
   F 467 Specification for Nonferrous Nuts for General Use
   F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
   F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
   F 594 Specification for Stainless Steel Nuts
   B 21 Specification for Naval Brass, Rod, Wire, Shapes, forgings, and Flat products with finished edges (Bar, Flat wire, and Strip)
   B 26 Specification for Aluminum-Alloy Sand Castings
   B 61 Specification for Steam or Valve Bronze Castings
   B 62 Specification for Composition Bronze or Ounce Metal Castings
   B 148 Specification for Aluminum-Bronze Sand Castings
   B 150 Specification for Aluminum Bronze Rod, Bar, and Shapes
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   F 594 Specification for Stainless Steel Nuts

2.2 ANSI Standards:
   ANSI B1.1 Unified Screw Threads
   ANSI B1.12 Class 5 Interference, Fit Thread

2.3 ISA Standards:
   S75.01 Flow Equations for Sizing Control Valves
   S75.02 Control Valve Capacity Test Procedure

2.4 Federal Specifications:
   QQ-B-637 Brass, Naval: Rod, Wire, Shapes, forgings, and flat products with finished edges (bar, flat wire, and strip)
   QQ-C-390 Copper Alloy Casting (Including Cast Bar)
   QQ-C-465 Copper-Aluminum Alloys (Aluminum Bronze) (Copper Alloy Numbers 606, 6014, 630, 632M, and 642); Rod, flat products with finished edges (Flat wire, strip, and Bar) shapes, and forgings
   QQ-N-281 Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, forgings, and structural and special shaped sections

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1 This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.


2 Annual Book of ASTM Standards, Vol 01.05.

3 Annual Book of ASTM Standards, Vol 01.01.

4 Annual Book of ASTM Standards, Vol 01.03.


6 Annual Book of ASTM Standards, Vol 02.01.


8 Annual Book of ASTM Standards, Vol 02.05.

9 Annual Book of ASTM Standards, Vol 15.08.

10 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

11 Available from Instrumentation, Systems, and Automation Society, 67 Alexander Dr., Research Triangle Park, NC 27709.

12 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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3. Terminology

3.1 Definitions of Terms Specific to This Standard: Descriptions of Terms Specific to This Standard:

3.1.1 accuracy of regulation—the amount by which the downstream pressure may vary when the valve is set at any pressure within the required set pressure limit and is subjected to any combination of inlet pressure, flow demand, and ambient temperature variations within the specified limits.

3.1.2 design pressure and temperature—the maximum pressure and temperature the valve should be subjected to under any condition; these are the pressure and temperature upon which the strength of the pressure-containing envelope is based.

3.1.3 hydrostatic proof test pressure—the maximum test pressure that the valve is required to withstand without damage; valve operation is not required during application of this test pressure, but the valve must meet all performance requirements after the pressure has been removed.

3.1.4 lockup pressure—the outlet pressure delivered by a pressure-reducing valve when the flow is reduced to zero; lockup pressure is always greater than set pressure, and in actual practice it may vary with the specific valve design, tolerances, method of sensing downstream pressure, and piping configurations.

3.1.5 nominal pressure—the approximate maximum pressure to which the valve will be subjected in service under normal conditions.

3.1.6 set pressure—the downstream pressure that the valve is set to maintain under a given set of operating conditions (that is, inlet pressure and flow); the valve should ideally be set at downstream pressure approximately equal to the midpoint of the set pressure limits (defined in 3.1.7).

3.1.7 set pressure limits (set pressure adjustable range)—the range of set pressure over which the valve can be adjusted while meeting the specified performance requirements.

4. Classification

4.1 Valves shall be of the following types and pressure ratings, as specified (see Section 5 and 6.1.21).

4.1.1 Type I—Pressurized spring chamber, and

4.1.2 Type II—Unpressurized spring chamber.

4.2 Pressure Ratings—Valves shall have nominal inlet pressure ratings of 150 or 250 psig (1034 or 1724 kPa), or as specified (see 6.1.21).

5. Ordering Information

5.1 Ordering documentation for valves in accordance with this specification shall include the following information, as required, to describe the equipment adequately.

5.1.1 ASTM designation and year of issue,

5.1.2 Valve specification code (see 6.1.21),

5.1.3 Quantity of valves,

5.1.4 Set pressure required,

5.1.5 Set pressure limits, if not listed in 7.1.4,

5.1.6 Face-to-face dimensions for valves, if not listed in Table 1,

5.1.7 Regulation accuracy required, if other than as given in 7.1.5,

5.1.8 When a choke feature is required (see 6.1.2),

5.1.9 When tailpieces and nuts are required (see 6.1.15),

5.1.10 Capacity requirement of valves, if not listed in Table 2 (see 7.1.6), and

5.1.11 Supplementary requirements, if any (see S1 through S4).

6. Valve Construction and Coding

6.1 Valves shall incorporate the design features specified in 6.1.1 through 6.1.21.

6.1.1 Materials of Construction—Materials shall be as specified in Table 3. All materials shall be selected to prevent corrosion, galling, seizing, excessive wear, or erosion where applicable. Cadmium plating is prohibited.
6.1.2 General Requirements—Valves shall be self-contained, spring-loaded, direct-operated, pressure-reducing valves incorporating a balanced valve element. Reduced pressure (not to exceed 200 psig (1379 kPa)) shall be sensed by a diaphragm and compared with a reference spring load. Any force imbalance shall be transmitted directly to and positively reposition a single-seated valve element to limit the set point error within the limits specified in 7.1.5. Type I valves shall be valves in which the spring chamber in combination with the body and bottom cap forms a pressure-containing envelope capable of withstanding the full hydrostatic proof test. These valves shall be specified for special applications in which it is necessary to contain the line media in the event of a failure that subjects the spring chamber to full inlet pressure. The spring chamber assembly need not be leakproof; however, it shall contain line media at hydrostatic proof test pressure without structural failure and shall limit external leakage to a small seepage (in drip form) past the adjusting screw threads and spring chamber joint. Type I valves shall also incorporate a choke feature on the poppet to limit capacity in the event of a diaphragm failure, where specified (see Section 5). Type II valves shall be valves in which the spring chamber does not form part of the pressure-containing envelope.

6.1.3 Pressure Envelope Rating—The nominal inlet (see 3.1.5), design (see 3.1.2), and hydrostatic proof test (see 3.1.3) pressures for the pressure-containing envelope (body, spring housing, and bottom cap) shall be as specified in Table 4. The design temperature (see 3.1.2) is also given in Table 4.

6.1.4 Body Passages—Body passages shall produce gradual changes in flow direction so as to reduce any effects of concentrated impingement and 90° turns. In portions of the valve subject to velocity increases and flow direction changes, such as immediately downstream of the seat, the 90° impingement against the walls at close range shall be avoided. The body cavity downstream of the seat shall present a high angle (70 to 90°) of incidence to the issuing jet. At points at which direct impingement at close range does occur and cannot be eliminated, the section thickness shall be increased substantially to provide adequate material to withstand the additional erosive effect.

6.1.5 Diaphragm Construction—The main diaphragm shall be clamped between flanges on the body and spring chamber to ensure a leaktight flange seal. The flange faces shall have sufficient width, and all edges in contact with the diaphragm shall be properly chamfered or rounded to prevent cutting or tearing of the diaphragm. The valve and diaphragm shall withstand a pressure differential across the diaphragm of twice the highest set pressure or 200 psig (1379 kPa), whichever is greater, for Type I valves. For Type II valves, this pressure differential shall be as follows: For valves of sizes up to 2 in.
TABLE 3 List of Materials

<table>
<thead>
<tr>
<th>Name of Parts</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body and bottom cap&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Valve bronze, Specification B 61, QQ-C-390, Alloy C92200.</td>
</tr>
<tr>
<td></td>
<td>Copper-nickel, MIL-C-20159, Alloy C96400.</td>
</tr>
<tr>
<td></td>
<td>Gun metal, QQ-C-390, Alloy C90300.</td>
</tr>
<tr>
<td></td>
<td>Nickel-aluminum-bronze per MIL-B-24480.</td>
</tr>
<tr>
<td>Spring chamber (Type I valves)</td>
<td>Same as for body and bottom cap.</td>
</tr>
<tr>
<td>Spring chamber (Type II valves)</td>
<td>Same as for body and bottom cap plus: Brass, QQ-B-637.</td>
</tr>
<tr>
<td>Stem&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Nickel-copper alloy, QQ-N-281, or QQ-N-288.</td>
</tr>
<tr>
<td>Guide bushings&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Nickel-copper-aluminum alloy, QQ-N-286.</td>
</tr>
<tr>
<td>Springs not subject to line media</td>
<td>300 series stainless steel per Specification A 313; QQ-S-763, QQ-W-390; Nickel-copper alloy, QQ-N-281; Nickel-copper-aluminum, QQ-N-286; Nickel plated steel per Specifications A 125, A 231, or A 689 plated to Specification B 689, Type 1, Class (x) 125. Specification B 637 (UNS N07500).</td>
</tr>
<tr>
<td>Metallic parts subject to line media</td>
<td>Nickel-copper alloy, QQ-N-281, QQ-N-286, or QQ-N-288.</td>
</tr>
<tr>
<td></td>
<td>Copper-nickel, MIL-C-20159, Alloy C71500.</td>
</tr>
<tr>
<td></td>
<td>Valve bronze, Specification B 61, QQ-C-390, Alloy C92200.</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>Nickel-copper-aluminum alloy, QQ-N-286.</td>
</tr>
<tr>
<td>Nonmetallic seals</td>
<td>Nitrile or fluorocarbon rubber or other materials when specified (see Section 5).</td>
</tr>
<tr>
<td>Disc insert&lt;sup&gt;c&lt;/sup&gt; and static seals</td>
<td>Nitrile or fluorocarbon rubber or other materials when specified (see Section 5).</td>
</tr>
<tr>
<td>Dynamic seals</td>
<td>Nitrile or fluorocarbon rubber or other materials when specified (see Section 5).</td>
</tr>
<tr>
<td></td>
<td>Specifications F 593, F 594, A 193, and A 194 (stainless steel 300 series).</td>
</tr>
</tbody>
</table>

<sup>a</sup>When threaded parts made of nickel-copper alloys, such as seat ring, guide bushings, and so forth are screwed into a bronze body, the threads on these parts as well as the mating threads in the body shall be given a corrosion-inhibitive coating (polysulfate chromate elastomer) per MIL-S-81733 to minimize the galvanic and crevice corrosion of threads.

<sup>b</sup>The guiding surfaces on the stem (guide posts) and the guide bushings shall have a minimum hardness differential of 50 Brinell hardness numbers. The softer of the two guiding surfaces shall have a minimum hardness of 200 Brinell.

<sup>c</sup>Hardness of the disc insert is to be Shore 75° ±5.

TABLE 4 Design and Test Pressures

<table>
<thead>
<tr>
<th>Nominal Inlet Pressure Rating, psig (kPa)</th>
<th>Design Pressures, psig (kPa)</th>
<th>Hydrostatic Proof Test Pressure, psig (kPa)</th>
<th>Design Temperature, °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 (1034)</td>
<td>150 (1034)</td>
<td>225 (1551)</td>
<td>165 (74)</td>
</tr>
<tr>
<td>250 (1724)</td>
<td>250 (1724)</td>
<td>375 (2586)</td>
<td>165 (74)</td>
</tr>
<tr>
<td>400 (2758)</td>
<td>400 (2758)</td>
<td>600 (4137)</td>
<td>165 (74)</td>
</tr>
<tr>
<td>700 (4826)</td>
<td>700 (4826)</td>
<td>1050 (7239)</td>
<td>165 (74)</td>
</tr>
</tbody>
</table>

and roundness requirements for all surfaces that establish main valve alignment shall ensure parallel disc/seal contact and free valve movement without sticking or binding in the assembled valve. The valve shall be designed so that these alignment requirements are maintained with interchangeable parts and under any additive tolerance (stackup) condition without requiring machining after assembly of the body and bottom cap. The bottom cap/body joint shall ensure, by positive means, proper alignment of the lower guide bushing to ensure repeated correct reassembly. The bottom cap shall be located by body guiding, that is, a close tolerance fit between machined diameters on the body and bottom cap rather than depending on studs or bolts for location. Where the bottom cap/body joint is of flanged construction, proper parallel alignment of the lower guide bushing shall be assured by metal-to-metal makeup of at least a portion of the flange faces, which shall be machined true. The finish of the guiding surfaces shall have a roughness height rating (RHR) of 32 or better. The guiding surfaces shall not be used as sealing surfaces.

6.1.7 Valving Element Balance—The valve element shall be completely pressure balanced when in the seated position. The dynamic seal shall be accomplished by use of either a diaphragm or a fully retained U-cup or O-ring. Where a U-cup
or O-ring is used, the surface moving against the seal shall have a finish of RHR 16 or better and shall not be used for guiding the stem.

6.1.8 Seat Ring—A replaceable threaded seat ring (or a piston chamber for valves with the cage construction design) shall be provided so that it can be replaced with hand tools (see 6.1.18) and does not require machining after assembly. The seat ring shall shoulder against the body to provide a positive pressure-tight joint in which the threads are not used to seal. Where a nonmetallic sealing element is used, a precision-dimensioned gland or cavity shall be provided in either the body or seat ring to ensure proper and controlled retention of the sealing element.

6.1.9 Bolting Requirements—The spring chamber/body flange and bottom cap/body flange (if applicable) shall be secured by one of the following methods:

(1) Bolts threaded the entire length and fitted with a nut on each end. Threads on bolts and nuts shall have a Class 2 fit in accordance with ANSI B1.1.

(2) Tap-end studs with a Class 5 interference fit at the tap end and a Class 2 fit at the nut end. The fit shall be in accordance with ANSI B1.12.

(3) Hexagonal head bolts or cap screws.

The bearing surfaces of nuts and bolts and their respective mating surfaces on the valve shall be cast or forged smooth and true or be finish-machined. The bottom cap/body joint may have either a flanged construction, in accordance with the above, or a threaded construction. A properly retained gasket or O-ring shall be provided to seal against external leakage.

6.1.10 Spring Construction—Springs shall not be fully compressed under any normal operation or adjustment of the valve. Spring ends shall be squared and ground.

6.1.11 Set Pressure Adjustment—The set pressure (see 3.1.6) shall be adjustable with the valve under pressure. The set pressure shall be increased by the clockwise rotation of the adjusting device. The adjusting device shall be provided with a locknut and cap or other suitable means to guard against an accidental change in set point. Set pressure shall be adjustable through a range of not less than 75 to 125% of the mid-range set pressure with the installed spring without replacing any internal parts (see Section 5).

6.1.12 Threads—Threads shall conform to ANSI B1.1. Provisions shall be incorporated, where necessary, to prevent the accidental loosening of threaded parts. Bolting shall generally have a Class 2 fit, in accordance with ANSI B1.1. The material, hardness, finish, and clearances of mating threaded parts shall prevent galling of the threads. Pipe threads shall not be used for main connections, but they may be used for low-stressed internal parts, such as attachment of a pitot tube. When required in Table 3, threads shall be coated.

6.1.13 Interchangeability—Parts having the same manufacturer’s parts numbers shall be directly interchangeable with each other with respect to installation and performance without requiring selection or fitting. In no case shall parts for a given valve be physically interchangeable or reversible unless such parts are also interchangeable or reversible with regard to function, performance, and strength.

6.1.14 Accessibility—Adjustment and repair of the valve shall be possible without removal from the line.

6.1.15 End Connections—Valve ends shall be in accordance with the applicable documents listed in Table 5. The valve end connection type shall be as specified (see Section 5 and 6.1.21). Unless otherwise specified in the ordering information (see Section 5), valves with union-ends shall be supplied with the male threadpieces only, without the tailpieces and the union nuts. Flanges and union-end thread pieces shall be cast or forged integral with the valve body. Inlet and outlet connections shall be of the same size and pressure rating.

6.1.16 Face-to-Face Dimensions—Face-to-face dimensions for valves shall be in accordance with Table 1. Face-to-face dimensions for valves not covered in Table 1 shall be as specified (see Section 5). For union-end valves, the face-to-face dimension is defined as the distance between the parallel faces of the threaded ends of the valve body.

6.1.17 Body Configuration—Valves shall have globe configuration with in-line inlet and outlet ports. Pressure lines, including the reduced pressure sensing line, shall be internally ported in the body.

6.1.18 Special Tools—Special tools shall not be required for installing or removing the valve from the pipe line. Special tools may be furnished for servicing valve internals if it can be demonstrated that use of the special tool saves labor or time. Special tools are defined as those tools not listed in the Federal Supply Catalog.

6.1.19 Painting—Except for the case of aluminum alloys, painting of the external surfaces of nonferrous metal castings, pipings, or other parts is not required. Parts made of aluminum alloys shall be given one coat of pretreatment per DOD-P-15328, Formula 117, and one coat of primer per TT-P-645, Formula 84.

6.1.20 Welding and Brazing—Welding and brazing shall be performed in accordance with MIL-STD-248 and MIL-STD-278.

6.1.21 Valve Specification Coding—Basic valve design features shall be specified and recorded using the valve coding system shown in Fig. 1. The valve specification code contains six fields of information, which describe the construction features of the valve. These six fields are each further assigned their respective codes per Tables 6-10.

7. Performance Requirements

7.1 All valves shall meet the following requirements:

7.1.1 Springs—Springs shall not exhibit a set in excess of the calculated allowable set (see S1.1.3).

7.1.2 Hydrostatic Proof Test—The pressure-containing envelope shall withstand internal hydrostatic pressure of 1.5 times the design pressure (see Table 4 and S1.1.4).

<table>
<thead>
<tr>
<th>TABLE 5 End Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Pressure Rating, psig (kPa)</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>150 (1034)</td>
</tr>
<tr>
<td>250 (1724)</td>
</tr>
<tr>
<td>400 (2756)</td>
</tr>
<tr>
<td>700 (4825)</td>
</tr>
</tbody>
</table>
7.1.3 Seat Tightness—The pressure increase after lockup (see 3.1.4) on the downstream (or regulated outlet) side of the valve shall not exceed 10% of the set pressure or 2.5 psi (17.24 kPa), whichever is greater, over a 15-min period (see S1.1.5).

7.1.4 Set Pressure Limits—Unless otherwise specified (see Section 5), the set pressure (see 3.1.7 and Table 10) shall be adjustable within the standard set pressure ranges of 5 to 30, 25 to 60, and 50 to 100 psig (34 to 207, 172 to 414, and 345 to 689 kPa). If required, more than one spring may be used to accomplish this.

7.1.5 Accuracy of Regulation—Unless otherwise specified (see Section 5), the valve shall provide an accuracy of regulation (see 3.1.1) per the following:

7.1.5.1 The downstream regulated pressure shall not deviate beyond the values listed in Table 11 when the flow through the valve is increased from zero to the rated capacity.

7.1.5.2 The downstream regulated pressure deviation from the set pressure shall not exceed 0.5 psi (3.45 kPa) for every 10-psi (69-kPa) change in upstream pressure when the upstream pressure is changed at the same flow rate condition.

7.1.6 Capacity Requirements—The minimum required valve flow coefficients ($C_v$) for Type I and II valves, based on the accuracy of regulation specified in 7.1.5, shall be in accordance with Table 2. The minimum required capacity for valves not listed in Table 2 shall be as specified (see Section 5). Valves shall meet the specified capacity required, or any intermediate capacity requirement, while maintaining the regulated pressure within the accuracy limits specified in 7.1.5, without instability and within the vibration requirements of 7.1.7.

7.1.6.1 Capacity Calculation—Calculation of the valve flow ($C_v$) shall be performed from test data (test calculations shall be in accordance with ISA S75.01 and tests in accordance with ISA S75.02) based on the following equations for turbulent flow:

$$C_v = \frac{\text{flow}}{F_p \sqrt{\text{inlet pressure} - \text{minimum delivered flow pressure}}} \quad (1)$$

where:

$F_p$ = piping geometry factor ($F_p = 1.0$ when pipe reducers are not used),

flow = US gal/min of water at 60°F (16°C),

inlet pressure = psig, and

minimum delivered flow pressure = the set pressure, minus allowable pressure deviation permitted, psig.

For example, a 1½-in. (38-mm), Type II, 150-psig (1034-kPa) rated valve with a 150-psig (1034-kPa) inlet water supply pressure and set at 20 psig (138 kPa). The valve delivers 125 gal/min when the minimum regulated downstream pressure drops to 15.5 psig (107 kPa) (that is, 20 psi (138 kPa) less 4.5 psi (31 kPa); note that Table 11 permits a deviation of 4.5 psi (31 kPa) in the regulated pressure).
This satisfies the minimum requirement listed in Table 2 for a 1½-in. (38-mm) valve set at 20 psig (138 kPa). For set pressures between those listed in Table 2, the minimum required $C_v$ shall be obtained by linear interpolation.

7.1.7 Vibration—The valves shall be resistant to Type I environmental vibration in accordance with MIL-STD-167-1. There shall be no resonant frequency from 0 to 33 Hz and no degradation of valve performance when excited in this frequency range (see S1.1.6.3).

7.1.8 Shock—The valve shall retain its set performance capability and suffer no structural damage or permanent deformation after shock testing in accordance with MIL-S-901 and MIL-STD-798 (see S1.1.7 and Section 5).

8. Tests

8.1 Each production valve shall pass the tests outlined below:

8.1.1 Hydrostatic Proof Test—Pressurize the pressure-containing envelope with water to the hydrostatic proof test pressure specified in Table 4. Hold for a minimum of 3 min, depressurize, and pressurize again for 3 additional min to verify conformance with Table 12.

8.1.2 Seat Tightness Test—With water applied to the valve inlet, at pressure equal to the nominal rating of the valve, set the valve lockup at the midpoint of the set pressure range. Measure the downstream pressure increase in a 15-min period in a dead-ended volume not exceeding 100 diameters of downstream piping to verify conformance with Table 12.

9. Marking

9.1 Body Markings—Valve bodies shall be permanently marked to show the following information:

9.1.1 Nominal size,

9.1.2 Pressure rating,

9.1.3 Manufacturer’s name or trademark, and

9.1.4 Flow direction arrow.

9.2 Identification Plates—An identification plate of corrosion-resistant metal shall be attached to the valve and shall list the following:

9.2.1 Manufacturer’s name,

9.2.2 Valve specification code,

9.2.3 Set pressure range, and

9.2.4 Manufacturer’s model or part number.

10. Quality Assurance System

10.1 The manufacturer shall establish and maintain a quality assurance system which will ensure that all the requirements of this specification are satisfied. This system shall also ensure that all valves will perform in a manner similar to those representative valves subjected to original testing for determination of the operating and flow characteristics.

10.2 A written description of the quality assurance system that the manufacturer will use shall be available for review and acceptance by the inspection authority.

10.3 The purchaser reserves the right to witness the production tests and inspect the valves in the manufacturer’s plant to the extent specified on the purchase order.

### SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of applicable supplementary requirements shall be agreed upon in writing by the manufacturer and the purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Initial Qualification Testing

S1.1 Qualification tests shall be conducted at a laboratory satisfactory to the customer and shall consist of the examination and tests outlined in Table 12 and specified in S1.1.1 through S1.1.7. Acceptance criteria shall be as given in Table 12.

S1.1.1 Qualification Test Sample—A sample valve shall be submitted for each type and rating for which qualification approval is desired (for sample size(s) required for shock qualification, see S1.1.7). Qualification approval, based on the examination and test of the sample, will then apply to all sizes of that type and rating covered by this specification (see S1.1.1.1). Detailed engineering drawings of the test valve and assembly drawings of all sizes of that type and rating shall be submitted with the test valve.

S1.1.1.1 Valves of other sizes may be tested upon specific approval by the customer. The use of only one valve size for qualification of a type and rating in accordance with this specification applies only where the test valve is representative of the basic design features of all sizes of the type and rating for which qualification is desired. The customer reserves the right to determine which variations are significant enough to require separate qualification testing.
S1.1.2 Examination Before Testing—Upon receipt of the qualification test sample, the sample valve(s) shall be disassembled and examined visually and dimensionally to determine conformance with the requirements of this specification and complete dimensional conformance to the detailed engineering drawings.

S1.1.2.1 Upon satisfactory completion of the examination specified in S1.1.2, the valve(s) shall be tested as specified in S1.1.3 through S1.1.7.

S1.1.3 Spring Test—The spring from the disassembled sample valve shall be examined visually and dimensionally as follows:

S1.1.3.1 The free spring length shall be measured and an allowance of 0.010 in. (0.254 mm) per inch of free spring length calculated. Fraction of inches of free spring length shall be prorated and added to the calculations for allowance.

S1.1.3.2 The spring shall be fully (solidly) compressed and released.

S1.1.3.3 Ten minutes after release, the spring shall be measured again.

S1.1.3.4 The spring shall not exhibit a set in excess of the allowance calculated in S1.1.3.1.

S1.1.4 Valve Body and Diaphragm Hydrostatic Proof Test—Sample valve body and valve diaphragm hydrostatic tests shall be performed to test the strength and soundness of the pressure-containing envelope. No structural failure, permanent deformation, damage to seating surfaces, or external leakage (except a slight seepage in drip form) from the spring chamber assemblies in Type I valves) shall be acceptable. A visual and dimensional inspection is required after testing (see S1.1.2).

S1.1.4.1 Type I Valve Pressure-Containing Envelope—The hydrostatic test pressure shall be 1.5 times the nominal inlet pressure or design pressure. Table 4 contains a listing of hydrostatic proof pressures. Valve internals shall be removed for the test.

S1.1.4.2 Type II Valve Pressure-Containing Envelope—This test shall be performed as above, except that the body/spring chamber shall be blanked off.

S1.1.4.3 Type I and II Valve Diaphragm Test—The inlet port shall be blanked off and the outlet section of the valve hydrostatically pressurized to create a pressure differential in accordance with 6.1.5. The valves shall be pressurized for 2 min, depressurized, and pressurized again for 2 min. The valve shall be examined at completion in accordance with S1.1.2.

S1.1.5 Lockup Pressure Test (Seat Tightness Test)—The sample valve shall be installed in a test setup that incorporates an accurate means of monitoring pressures at the inlet and outlet (regulated flow) of the valve. The outlet piping shall be arranged so that it shuts off while in a flooded state with no air binding (entrapment) for approximately 100 pipe diameters downstream of the valve. With hydrostatic pressure equal to the rated nominal inlet pressure of the valve applied to the inlet, the valve shall be set to lockup at the midpoint of its pressure range setting. The pressure increase after lockup on the closed downstream (or regulated outlet) side of the valve shall not exceed 10% of the set pressure or 2.5 psi (17 kPa), whichever is greater, over a 15-min period. If the valve fails to meet these requirements, it shall be given a visual and dimensional examination (S1.1.2) to determine the cause.

S1.1.6 Composite Test—The sample valve which has passed the seat tightness test shall be installed in a test setup that incorporates an accurate means of monitoring the flow rate and pressures at the inlet and outlet of the valve. This test setup will facilitate establishment of set pressure limits/accuracy of regulation, capacity, and vibration response.

S1.1.6.1 Set Pressure Limits/Accuracy of Regulation—This test shall be conducted in two parts:

1. Measure the downstream pressure at the minimum and maximum of the set pressure range by applying an inlet pressure equal to the nominal valve rating and varying flow from lockup to full flow to lockup. The droop characteristics (fall off in the downstream pressure) shall be determined by following the procedure in 7.1.6.1. The downstream pressure variation shall not exceed the values listed in Table 11.

2. Adjust the set pressure at the mid range of the set pressure adjustment range of the spring. These set pressures shall be 20 psig (138 kPa) for the 5 to 30 psig (34 to 207 kPa) spring, 40 psig (276 kPa) for the 25 to 60 (172 to 414 kPa) psig spring, and 75 psig (517 kPa) for the 50 to 100 psig (345 to 689 kPa) spring. Keeping the flowrate constant, vary the upstream pressure from (10 + set pressure) psig to (110 + set pressure) psig and measure the downstream pressure. The downstream pressure shall not vary by more than 5 psi (34 kPa).

S1.1.6.2 Capacity Requirements—Following the above, the valve capacity shall be tested. It shall conform to the requirements of 7.1.6.

S1.1.6.3 Vibration—The valve shall be vibration tested with the nominal inlet pressure rating applied to the inlet port and the valve set at approximately the midpoint of the set pressure range. Performance requirements are set forth in 7.1.7.

S1.1.7 Shock Test—Sample size(s) for shock qualification testing shall be in accordance with MIL-STD-798. The valve shall be subjected to the high-impact mechanical shock requirements for Grade A, Class I of MIL-S-901 to determine its resistance to high-impact mechanical shock. The shock test shall be performed with the nominal hydrostatic pressure applied to the inlet port. During impact, an instantaneous, reversible pressure excursion is allowable. After the test, the valve shall be subjected to a visual and dimensional check (S1.1.2) and the tests described in 8.1.1 and 8.1.2. The valve shall meet the requirements of 7.1.8.

S2. Examinations

S2.1 Lot—For the purpose of sampling, all valves of the same type and size offered for delivery at one time shall be considered a lot.

S2.2 Sampling for Visual and Dimensional Examination—A random sample of valves shall be selected from each lot as shown below and shall be examined as specified in S2.3 and S2.4. The failure of any valve in a sample to pass the examination specified in S2.3 and S2.4 shall be cause for rejection of the lot.

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 25</td>
<td>1</td>
</tr>
<tr>
<td>26 to 65</td>
<td>2</td>
</tr>
</tbody>
</table>
S2.3 Visual Examination—A visual examination shall be made of the sample valves selected in accordance with S2.2 to verify conformance to the requirements of this specification.

S2.4 Dimensional Examination—A dimensional examination shall be made on the sample valves selected in accordance with S2.2 to verify conformance with the approved master drawing.

S3. Packaging and Marking Requirements

S3.1 Preservation, Packing, and Marking—Valves shall be individually preserved Level A or commercial, packed Level A, B, C, or commercial as specified (see 5.1.11), and marked in accordance with MIL-V-3.

S3.2 Cushioning, Dunnage, and Wrapping Materials:

S3.2.1 Level A Preservation and Levels A, B, and C Packing—Utilization of all types of loose-fill materials for shipboard use is prohibited.

S3.2.2 Commercial Preservation, and Packing—When loose-fill type materials are used for cushioning, filler, and dunnage, all containers (unit, intermediate, and shipping) shall be marked or labeled with the following information:

“CAUTION
Contents cushioned, etc., with loose-filled material. Not to be taken aboard ship. Remove and discard loose-fill material before shipboard stowage. If required, recushion with polyurethane foam, or transparent flexible cellular material.”

S3.3 Cushioning, filler, dunnage, and wrapping materials selected shall have properties (characteristics) resistant to fire.

S3.4 The valve CID/APL number shall be stamped on the valve name plate.

S4. Quality Assurance

S4.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.

S4.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.

S4.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the right of the manufacturer to establish, and from time to time to alter, the form of organization the manufacturer considers appropriate for its work. Individuals performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

S4.4 Review of the Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.

S4.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.

S4.6 Purchase Control—The manufacturer shall ensure that all purchased materials and services conform to specified requirements and that all purchase orders include complete details of the material and services ordered.

S4.7 Material Control—The manufacturer shall have a system for material control that ensures that the material received is properly identified and that any required documentation is present, identified as to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of the material during the manufacturing process by a system that identifies the inspection status of the material throughout all stages of manufacture.

S4.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are conducted under controlled conditions using documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.

S4.9 Quality Control Plan—The quality control plan of the manufacturer shall describe the fabrication operations, including examinations and inspections.

S4.10 Welding—The quality control system shall include provisions for ensuring that the welding conforms to specified requirements. Qualifications of the welders shall meet the appropriate standards, and the qualification records shall be made available to the inspection authority if required.

S4.11 Nondestructive Examination—Provision shall be made to use nondestructive examination, as necessary, to ensure that materials and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer or qualified by a recognized national body, and their authorizations and qualification records shall be made available to the inspection authority if required.

S4.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.

S4.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.

S4.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of materials during all stages of manufacture and shall be able to distinguish between inspected and non-inspected material.

S4.15 Calibration of Measurement and Test Equipment—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring, and test equipment to be used in verifying conformance to the specified requirements. Such calibration shall be traceable to a national standard, and calibration records shall be maintained.
S4.16 Records Maintenance—The manufacturer shall have a system for the maintenance of inspection records, radiographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S4.17 Sample Forms—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S4.18 Inspection Authority—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with either originals or copies of such documents.
Standard Practice for Platforms in Cargo Tanks

This standard is issued under the fixed designation F 1385; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides design, construction, and installation criteria for platforms in cargo tanks.

1.2 Where platforms are attached to ladders see Figs. 1-4.

1.3 The values stated in SI (metric) units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A 36M Specification for Carbon Structural Steel
2.2 Military Specification:
MIL-G-18015 Grating, Metal, Other than Bar Type (Shipboard Use)
3. Federal Standard:
FED-SPEC-RR-C-271 Chain and Attachments, Welded and Weldless
4. Absolute Standard:
American Bureau of Shipping Rules for Building and Classing Steel Vessels
5. AWS Standard:
AWS D1.1 Structural Welding Code—Steel
6. Other Standards:
SAE-AMS-C-27725 Coatings, Corrosion Preventative, Polyurethane, for Aircraft Integral Fuel Tanks for Use to 250 Degrees F (121 Degrees C)

3. Significance and Use

3.1 This practice establishes the procedure for the construction and installation of platforms to be fabricated and installed by the shipyards within the cargo tanks.

4. Materials and Manufacture

4.1 Materials:

4.1.1 Gratings—1.8-kg (4-lb) expanded metal fabricated in accordance with MIL-G-18015.

4.1.2 Flanged Plate Supports—Fabricated from 10 by 380 mm (approximately 3/8 by 15 in.) with a 75-mm (approximately 3-in.) flange of carbon steel plate in accordance with Specification A 36/A 36M.

4.1.3 Angle Supports—75- by 75- by 10-mm (approximately 3- by 3- by 3/8-in.) structural angles of carbon steel in accordance with Specification A 36/A 36M.

4.1.4 Stanchions—25-mm (approximately 1-in.) diameter carbon steel.

4.2 Manufacture:

4.2.1 Platforms shall be constructed as shown in Figs. 1-4.

4.2.2 The dimensions indicated in Figs. 1-4 are for the commonly used sizes. However, dimensions can be modified to suit other existing structures.

4.2.3 Platforms shall be designed to support static loads of at least 14 kPa (approximately 300 psf).

4.2.4 Platforms shall be locally reinforced where greater loads are contemplated for removal or disassembly of machinery.

4.2.5 All welding shall be in accordance with American Bureau of Shipping Rules for Building and Classing Steel Vessels or AWS D1.1.

4.2.6 Tolerances shall be ±6 mm (approximately 1/4 in.).

5. Dimensions

5.1 Openings in railings serving ladders to lower levels shall not be more than 690 mm (approximately 27 in.) wide.
5.2 Safety chains with snap hooks shall be provided to close such openings at heights of 530 and 1060 mm (approximately 21 and 42 in.) above the walking surface. Chain shall be welded and shall be in accordance with FED-SPEC-RR-C-271.

6. Workmanship, Finish, and Appearance

6.1 Platforms shall be free of all sharp edges, burrs, projections, weld splatter, and other defects that might be injurious to personnel or equipment, or both.

6.2 For cargo tanks carrying cargo other than fuel oils, coat platforms with one coat 3.0-MIL dry film thickness inorganic zinc silicate following surface preparation in accordance with the Steel Structure Painting Council Specifications or the manufacturer’s paint instructions.

6.3 For spaces carrying fuel oil cargo, one coat of 3.0-MIL dry film thickness of corrosion preventive coating shall be applied to the platforms in accordance with SAE-AMS-C-27725.

6.4 Grating sections are to be tested in accordance with MIL-G-18015 or as follows: Support a section of grating on

7 Available from Steel Structures Painting Council (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222–4656.
two supports each 25 mm (approximately 1 in.) wide and 915 mm (approximately 36 in.) apart. The test load is to be three times the design load. The test load is to be suspended from a bar 610 by 50 mm (approximately 24 by 2 in.) applied across the grating midway between the supports.

7. Keywords

7.1 cargo tank access; cargo tank gratings; cargo tank platforms; cargo tanks; platforms
FIG. 3 Cargo Platform—Girder

DETAIL "D-D"

DETAIL "E-E"

PLAN VIEW TO GIRDER

FIG. 3 Cargo Platform—Girder
FIG. 4 Cargo Platforms Showing Typical Sections

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.
Standard Guide for Construction of Sounding Tube and Striker Plate for Tank Sounding

This standard is issued under the fixed designation F 1386; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers design and construction criteria for striker plates and sounding tubes, excluding deck penetrations and caps, for use with sounding rods or tapes in freshwater, saltwater, and oil tanks.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Carbon Structural Steel
A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
F 722 Specification for Welded Joints for Shipboard Piping Systems
F 1155 Practice for Selection and Application of Piping System Materials

2.2 ANSI Standards:

B16.5 Pipe Flanges and Flange Fittings
B16.9 Factory Made Wrought Steel Butt Welding Fittings
B16.11 Forged Steel, Socket Welding and Threaded Fittings
B16.28 Wrought Steel, Butt Welding, Short Radius Elbows and Return
B31.1 Power Piping

2.3 ABS Standard:

American Bureau of Shipping Rules for Building and Classing Steel Vessels

2.4 AWS Standard:

AWS D1.1 Structural Welding Code

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 external sounding tube—a sounding tube located outside the boundaries of the tank being sounded.

3.1.2 internal sounding tube—a sounding tube located inside the tank being sounded.

3.1.3 sounding—measurement by sounding; a place or part of a body of liquid where a hand sounding line will reach bottom.

4. Classification

4.1 Type I—Internal sounding tube, with separate striker plate.

4.2 Type II—Internal sounding tube, with attached striker plate.

4.3 Type III—Internal sounding tube, with angle striker plate.

4.4 Type IV—External sounding tube.

5. Significance and Use

5.1 Sounding tubes may be fabricated from 1½ NPS or larger. Only when otherwise specified, Schedule 40 components, manufactured from the list of material indicated in Practice F 1155 and Specification A 53/A 53M, Grade S or Grade ERW. In addition, sounding tubes may be fabricated in stainless steel for stainless steel tanks.

5.1.1 Sounding tubes passing through or terminating in fuel tanks, potable water tanks, or clean salt water ballast tanks should be constructed of 70-30 copper nickel, but other suitable material is acceptable.

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1 Available from American Bureau of Shipping (ABS), ABS Plaza, 16855 Northchase Dr., Houston, TX 77060.

5.2 Striker plates shall be fabricated in accordance with Specification A 36/A 36M.

5.3 The fittings shall be designed in accordance with ANSI B16.5, B16.9, B16.28, or B16.11 as applicable (See Table 21 in Practice F 1155), and the installation shall be in accordance with ANSI B31.1 as modified by Specification F 722. These standards cover the fitting tolerances.

5.4 Some cargo may preclude the use of materials specified in this guide. However, configuration examples are applicable for all applications.

5.5 When a sounding tube is combined with the air escape, either three 1¼-in. (approximately 30-mm) diameter holes approximately 12 in. (305 mm) from the tank top equally spaced or six ½-in. (approximately 15-mm) diameter holes approximately 6 in. (150 mm) from the tank top equally spaced can be used for perforations. See Fig. 2.

5.6 Figs. 1-4 are guidance details.

6. Installation of Sounding Tubes

6.1 Locate sounding tubes as close as possible to the lowest part of the tank.

6.2 Type I, II, and III sounding tubes, excluding oil products, shall be perforated as shown in Fig. 1, Fig. 2, and Fig. 3 respectively, for ventilation.

6.2.1 Type IV sounding tubes are only allowed where the tank cannot be penetrated from the top because of an unavoidable situation, such as a prohibitive location (see Fig. 4).

6.3 Slope and curvature shall be kept to a minimum, and under no circumstances shall the slope be permitted to exceed 45° from the vertical. Radius of curvatures up to a minimum of 10 ft (approximately 3 m) will be permitted where unavoidable.

6.4 Tubes may be provided with flanged take down connections, approximately 18 in. (455 mm) from the tank bottom.
6.4.1 Tubes shall be terminated close enough to tank bottoms to prevent hangup of a sounding device or a thief sampler when they are being withdrawn from a tank.

6.4.2 The inside edges of sounding tube shall be smoothed to prevent hanging up of a sounding device or thief sampler when they are being withdrawn from the tank.

6.5 Tubes shall be adequately supported to withstand both static and dynamic loads.

6.6 Welding shall be in accordance with American Bureau of Shipping Rules for Building and Classing Steel Vessels or AWS D1.1.

SUPPLEMENTARY REQUIREMENTS

S1.1 To ensure the fluid in the sounding tube is representative of the fluid in the tank when taking fuel samples, 1/2-in. (approximately 15-mm) diameter holes, 6 in. (150 mm) apart are drilled in the sounding tubes throughout its length in the tank it serves.
Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings

1. Scope
1.1 This specification establishes the performance characteristics required for mechanically attached fittings (MAFs) for use in piping and tubing systems. These fittings directly attach to pipe or tube by mechanical deformation of the pipe or tube or fitting, or a combination thereof, creating a seal and a restrained joint. The seal may be created via the mechanical deformation or created independently. Successful completion of the tests described constitutes completion of the technical portion of the qualification process.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified in part or whole by the purchaser in the order. Unless otherwise specified, U.S. Navy contracts shall invoke the supplementary requirements in whole.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following safety hazards caveat applies only to the tests listed in Section 13 and the tests described in the Supplementary Section and the Annex of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.5 Unless specific MAF types are specified, the term “MAF” shall apply to all types described herein.

1.6 The tests specified in Section 13 and described in Annex A1 and Supplementary Requirements are applicable only to ascertain the performance characteristics of MAFs. These tests are not intended for use in the evaluation of non-MAF products.

1.7 A fire performance test is specified in Supplementary Requirement S7. This test provides general guidelines to determine the responsiveness of MAFs when subjected to fire. This test should not be considered for use to evaluate non-MAF products.

2. Referenced Documents
2.1 ASTM Standards:
A 105/A 105M Specification for Carbon Steel Forgings for Piping Applications
A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A 108 Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality
A 109/A 109M Specification for Steel, Strip, Carbon (0.25 Maximum Percent), Cold-Rolled
A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
A 276 Specification for Stainless and Steel Bars and Shapes

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.

A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes
A 380 Practice for Cleaning, Descaling, and Passivation Stainless Steel Parts, Equipment, and Systems
A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings
A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
A 479/A 479M Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
A 766/A 766M Specification for Forgings
B 16 Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines
B 21 Specification for Naval Brass Rod, Bar, and Shapes
B 111 Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
B 117 Practice for Operating Salt Spray (Fog) Apparatus
B 122/B 122M Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar
B 124 Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
B 154 Method for Mercurocyanate Nitrate Test for Copper and Copper Alloys
B 164 Specification for Nickel-Copper-Alloy Rod, Bar, and Wire
B 251 Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
B 371 Specification for Copper-Zinc-Silicon Alloy Rod
B 564 Specification for Nickel Alloy Forgings
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium
E 511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat Flux Gage
E 1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies

2.2 Federal Specifications:

2.3 Military Specifications:

2.4 Military Standards:

2 Annual Book of ASTM Standards, Vol 02.01.
3 Annual Book of ASTM Standards, Vol 03.02.
5 Annual Book of ASTM Standards, Vol 02.05.
6 Annual Book of ASTM Standards, Vol 03.02.
7 Annual Book of ASTM Standards, Vol 15.03.
8 Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
3. Terminology

3.1 Definitions:

3.1.1 class, n—a group of MAFs of a particular design with the dimensions proportional to pipe or tube outside diameters, made from the same material grade (or combination of grades), for the same rated pressure, or for a rated pressure inversely proportional to the diameter.

3.1.1.1 Discussion—Class designation for MAF is assigned based upon the rated pressure used to test the MAF design.

3.1.2 failure, n—any leakage or joint separation unless otherwise determined to be due to a tubing/pipe or fitting defect.

3.1.3 fitting, n—connecting device used to join multiple pipes or tubes or other MAFs together to create a working system.

3.1.3.1 Discussion—Shapes such as couplings, unions, elbows, tees, crosses, plugs, adapters, reducers, flanges, and special shapes are used as needed to fulfill MAF system design specifications.

3.1.4 joint, n—interface between pipe or tube and MAFs where the seal is maintained or mechanical holding strength is applied or maintained within the overall MAF design.

3.1.5 leakage, n—the escape of fluid or gas from any point of the MAF, including the MAF joint interface, sufficient to drop or flow from the point of formation or gas bubbles rising to the surface after the first minute of submersion.

3.1.6 mechanically attached fitting (MAF), n—a fitting that is directly attached to pipe or tube by mechanical deformation of the pipe/tube or fitting, or both, creating a seal and a restrained joint. The seal may be created via the mechanical deformation or created independently.

3.1.7 penalty run, n—a penalty run is performed with penalty run MAF specimens when the original MAF test specimen leaks or separates during testing as a result of any cause that is not related to the design of the MAF being qualified.

3.1.8 penalty run MAF specimens, n—additional specimen(s) that are tested in the place of the original specimen(s) (see 3.1.7).

3.1.8.1 Discussion—These additional MAF specimen(s) are assembled using the same methods along with additional MAFs of the same type, grade, class, and configuration and additional pipe or tube with the same wall thickness and material conditions as the original test specimen.

3.1.9 permanent MAF, n—a fitting whose joint(s) attach directly to the pipe or tube to join two or more pipes or tubes or other MAFs in a combination of pipes or tubes and components. In either case, the permanent MAFs cannot be disassembled and reused after initial assembly.

3.1.10 pipe, n—hollow round product conforming to the dimensional requirements for nominal pipe size (NPS) as tabulated in ANSI B36.10, Table 2.

3.1.11 rated pressure, n—the manufacturer’s recommended in-service pressure assigned to the MAF (see 3.1.15).

3.1.12 separable MAF, n—a fitting whose joint(s) attach directly to the pipe or tube to join two or more pipes or tubes or other MAFs in a combination of pipes or tubes and components. Once assembled, the separable MAFs can be disassembled and reassembled a multiple number of times.

3.1.12.1 Discussion—Some subcomponents of separable MAFs may become permanently attached to the pipe or tube without affecting the function of the joint.

3.1.13 specimen, n—a prepared assembly consisting of a MAF assembled onto a preselected pipe or tube. The specimen is placed into a controlled environment and tested to determine if the MAF assembly meets the requirements specified in the test being performed.

3.1.14 test pressure, n—a selected pressure used during testing, which is based upon the rated pressure (see 3.1.13) of the MAF or pipe or tube, whichever is lower, times the factor specified for each test (that is, 1.25, 1.50, 2.00, 4.00, and so forth).

3.1.15 tube, n—hollow round product which is usually specified with respect to outside diameter and wall thickness.

4. Classification

4.1 MAFs are classified into the following design types:

NOTE 1—Each MAF type may consist of more than one material and class.

4.1.1 Type I: Radially Swaged MAF (Permanent)—A portion of the MAF diameter is reduced mechanically by means of an installation tool through radial compression to provide an intimate joint. The properly installed MAF has a circumferential deformation of predetermined dimensions.

4.1.2 Type II: Flared MAF (Separable)—An assembly that consists of a body, nut, and sleeve. The MAF is designed to mate with a tube or other component which has been flared or

14 Available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096.
15 Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.
machined to a specific angle. The flared tube end is positioned onto the MAF body cone or seat. The nut is then tightened to the body thread, thus providing a tube-to-MAF seal through mechanical retention.

4.1.3 Type III: Flareless (Bite-Type) MAF (Separable)—An assembly having a ferrule, nut, and body. The ferrule penetrates the outside of the tubing, thus providing a pressure seal and holding mechanism.

4.1.4 Type IV: Grip-Type MAF (Separable)—An assembly having one or two ferrules that are compressed into the surface of the tube. In the case of the two-ferrule MAF, the forward ferrule provides the primary seal through radial compression around the outer diameter of the tube. The rear ferrule acts as the primary mechanical holding device. In the case of the single-ferrule design, the ferrule is used to seal and act as the primary mechanical holding device.

4.1.5 Type V: Shape Memory Alloy (SMA) MAF (Permanent)—Mechanically attached fittings that use SMA to provide the mechanical force required to produce a metal-to-metal seal between the pipe or tube and the MAF. The metal-to-metal seal that is formed is a “live crimp” since the pipe or tube and the SMA are in a state of dynamic equilibrium. The SMA maintains a permanent inward radial force on the pipe or tube at all times. The MAF body itself may be manufactured from a nonshape memory metal and used in conjunction with a driver made from SMA.

4.1.6 Type VI: Axially Swaged MAF (Permanent)—Mechanically attached fittings that have machined swaging rings telescopically “press fit” from the extremities toward the center of the MAF body. An installation tool advances the swaging rings axially over the MAF body into a seated and locked position. The swage rings compress the MAF body onto the pipe or tube forming a metal-to-metal seal. The seal is permanently maintained by the force radially exerted by the swaging rings onto the sealing interface.

4.2 The MAFs shall be made from one or more of the following material grades:

4.2.1 Grade A—Carbon steel.
4.2.2 Grade B—Stainless steel.
4.2.3 Grade C—Nickel-copper.
4.2.4 Grade D—Copper-nickel.
4.2.5 Grade E—Brass.
4.2.6 Grade F—Nickel titanium.

4.3 The MAF rated pressure may be one of the following classes:

Note 3—The rated pressure may differ within the size range of a MAF being qualified (see 3.1.1).

4.3.1 Class 1—1.38 MPa (200 psi) maximum.
4.3.2 Class 2—2.76 MPa (400 psi) maximum.
4.3.3 Class 3—4.83 MPa (700 psi) maximum.
4.3.4 Class 4—6.90 MPa (1000 psi) maximum.
4.3.5 Class 5—10.34 MPa (1500 psi) maximum.
4.3.6 Class 6—13.79 MPa (2000 psi) maximum.
4.3.7 Class 7—20.69 MPa (3000 psi) maximum.
4.3.8 Class 8—25.86 MPa (3750 psi) maximum.
4.3.9 Class 9—34.48 MPa (5000 psi) maximum.
4.3.10 Class 10—41.37 MPa (6000 psi) maximum.

5. Ordering Information

5.1 Orders for MAFs under this specification shall include the following:
5.1.1 ASTM designation, title, number, and year of issue;
5.1.2 Quantity of fittings (MAF);
5.1.3 Size, nominal pipe size (NPS), or outer diameter (OD);
5.1.4 Type (I, II, III, IV, V, or VI);
5.1.5 Material grade (see 4.2, 6.1, or Table 1),
5.1.6 Class (see 3.1.1 and 4.3);
5.1.7 MAF shape (that is, straight, elbow, cross, union, coupling, and so forth) (see 3.1.3);
5.1.8 Supplementary requirements, if any;
5.1.9 Other requirements agreed to between the purchaser and the manufacturer; and
5.1.10 Inspection and acceptance of MAFs as agreed upon between the purchaser and the supplier (see Section 14).

5.2 Optional Ordering Requirements:
5.2.1 Certification (see Section 15);
5.2.2 Special marking requirements (see Section 16 and S1.5).

6. Materials and Manufacture

6.1 MAF Material—The MAF material used may be as specified in Table 1 or may be other materials not specified in Table 1, as agreed to between the manufacturer and the purchaser.

6.1.1 All types may be manufactured from wrought bars, forgings, castings, pipe, or tube.
6.1.2 Flow of Grain—MAFs machined from hot- or cold-drawn bars shall have their longitudinal axis parallel to the longitudinal axis of the bar with at least the center one third of the bar removed during the manufacturing process unless testing shows the center material to be free of injurious defects.

6.2 Material Quality—The material shall be of such quality and purity that the finished product shall have the properties and characteristics to meet the performance requirements of this specification.

6.2.1 The manufacturer is encouraged to use materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. Used or rebuilt products shall not be used.

Note 4—The term “recovered materials” is interpreted as those materials that have been collected or recovered from solid waste and reprocessed to become a source of raw material, as opposed to extra virgin raw materials.

6.3 Seal Materials—Seals used with MAFs shall be as specified in Table 1.
6.4 Surface Applications and Coatings—Surface applications and coatings if applicable, shall be applied and tested in accordance with the requirements specified in Table 2.
6.5 MAF Fabrication—MAFs fabricated from two or more parts may be welded. The use of brazing or soldering is not permitted.
6.5.1 Welding procedure qualification and welding operator performance qualification shall be in accordance with ASME Section IX. Welding process shall be in accordance with MIL-STD-278. Welded MAFs shall be tested in accordance with the requirements as specified in 13.4.3.

6.5.2 The welding procedure qualification test shall duplicate the joint configuration to be used in production.

6.6 Processing Stainless Steel Forgings—Austenitic stainless steel components manufactured by hot forge or other sensitizing processes shall be solution annealed and certified free of intergranular precipitation. Practice A 262 shall be used to evaluate carbide precipitation in stainless steels.

### Performance Requirements

7.1 Testing Requirements—MAFs shall be subjected to the standard performance tests specified in 13.1 and Table 3. The tests are described in the Annexes. Supplementary tests specified in 13.2 and Table S1.1 shall be performed when invoked in the order or contract by the purchaser.

<table>
<thead>
<tr>
<th>Type</th>
<th>Straight</th>
<th>Shape</th>
<th>Nut/Ring</th>
<th>Sleeve or Ferrule</th>
<th>Backup Washer</th>
<th>Seal Material</th>
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</thead>
<tbody>
<tr>
<td>Grade A: Carbon Steel</td>
<td></td>
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<tr>
<td>I</td>
<td>A 108A</td>
<td>A 576</td>
<td>A 108</td>
<td>.</td>
<td>.</td>
<td>MIL-R-83248/1</td>
</tr>
</tbody>
</table>

Grade B: Stainless Steel

| II | A 312/A 312MA | QQ-S-763C | A 312/A 312MF | . | . | MIL-R-83248/1 |
| III | A 479/A 479M | A 182/A 182M | A 479/A 479MF | . | . | |
| IV | A 479/A 479M | A 182/A 182M | A 479/A 479MF | . | . | A 167 |
| VI | A 312/A 312MF | A 182/A 182MK | A 312/A 312MF | . | . | D |

Grade C: Nickel Copper

| II | B 164 | B 564 | B 164 | B 164 | A 167 |
| III | B 164 | A 564/A 564M | B 164 | B 164 | A 167 |
| IV | B 164L | B 564L | B 164L | B 164L | A 167 |

Grade D: Copper Nickel

| II | MIL-C-15726MD | MIL-C-20159MD | MIL-C-15726MD | . | . | MIL-R-83248/1 |
| III | B 122/B 122M | B 122/B 122M | B 122/B 122M | B 122/B 122M | A 167 |
| VI | MIL-C-15726MD | MIL-C-20159MD | MIL-C-15726MD | . | . | . |

Grade E: Brass

| II | B 16 | B 124 | B 16N | B 111C | . | . |
| IV | B 16N | B 124N | B 16N | B 16N | . | . |

Grade F: Nickel Titanium

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| Alternate material in conformance to Specification A 106 (Grade B) may be used. |
| Alternate material in conformance to Specification A 108 may be used. |
| When required by the MAF design, O-rings in accordance with SAE J515 shall be used to connect the MAF end. |
| No O-rings used to connect the MAF end. |
| Alternate material in conformance to Specification A 234/A 234M may be used. |
| Alternate material in conformance to MIL-P-24691/3 may be used. |
| 304, 304L or 316, 316L material may be used. |
| Alternate material in conformance to Specification A 276 may be used. |
| Alternate material in conformance to AMS 5643 may be used. |
| Alternate material in conformance to Specification A 403/A 403M may be used. |
| Alternate material in conformance to QQ-N-281 may be used. |
| Alternate material in conformance to MIL-T-16420 may be used. |
| Alternate material in conformance to Specification B 21 may be used. |
| Alternate material in conformance to Specification B 371 may be used. |
| Alternate material in conformance to QQ-B-626 may be used. |
| In accordance with the manufacturer’s specification. |
7.1.1 These tests shall be repeated any time changes are made in the design, material, or manufacturing process, which in the opinion of the purchaser, may degrade the performance of MAFs.

7.2 Intermixing of MAF Subcomponents—The intermixing by the purchaser of subcomponents of the same design, but of different brands or trade names, is not permitted unless specifically authorized by the manufacturer.

7.2.1 When subcomponents of different brands, trade names, or manufacturers are used, the manufacturer testing the MAF design shall specify this information in the test report.

7.3 Qualification Requirements—MAFs shall be tested using specimens of the same type, grade (or combination of grades), and class. The pipe or tube selected for the technical qualification to this specification shall meet the requirement specified in 7.3.4. Technical qualification of the MAF assembly shall be based upon successful completion of all required testing. Each MAF design is only qualified for use with the pipe or tube material and minimum to maximum wall thickness tested or extended by interpolation (see 7.3.2 and 7.3.3).

7.3.1 Except as required by Annex A11 (Mercurous Nitrate Test), all MAFs tested shall be comprised of an equal number of specimens from the smallest and largest sizes within the size range of the MAF type, grade, and class being tested.

7.3.1.1 Test one or more intermediate sizes if the ratio of the minimum and maximum pipe or tube outside diameter to be tested is equal to or more than five.

7.3.2 Through reasonable interpolations between the MAF sizes tested, all other sizes of MAFs within the same type, grade (or combination of grades), and class, will be considered acceptable if the MAF specimens pass all of the testing requirements specified by the purchaser. Extrapolation is not acceptable.

7.3.3 Acceptance of tees, elbows, and other shapes within the same class, may be accomplished by parametric analysis (see 7.3.3.1), as agreed to between the manufacturer and the purchaser based on the acceptance of couplings.

7.3.3.1 If tees, elbows, and other shapes are made from a different raw material form than the coupling (for example, tees and elbows manufactured from castings versus couplings manufactured from solid bar or round tube), this alternate material form shall undergo the same test regimen as the MAF manufactured from solid bar or round tube, this alternate material form shall undergo the same test regimen as the MAF manufactured from solid bar or round tube.

7.3.4 Recommended pipe or tube for use with MAFs may be qualified throughout its wall thickness range, when pipe or tube of a minimum and maximum wall thickness are used within the test specimens being qualified.

7.3.5 The MAFs may incorporate non-MAF features that are part of a MAF configuration shall meet the current issue of existing military and commercial documents (as applicable). Qualification of the non-MAF features are not within the scope of this specification.

7.4 Test Report—Upon completion of testing, a test report shall be written and maintained on file during the life cycle of
the design. A copy of this report shall be made available upon request from the purchasing activity.

7.4.1 A failure during testing shall be analyzed and the failure analysis (see 11.3.1 and 11.3.2) and corrective action shall be included in the test report.

7.4.2 A retest as specified in Section 11 may be allowed when failure of the original assembly occurs during testing. When retesting is permitted, the failure analysis and corrective action shall be included in the test report as specified in 7.4.1.

7.5 Test Equipment and Inspection Facilities—The manufacturer shall ensure that test equipment and inspection facilities of sufficient accuracy, quality, and quantity are established and maintained to permit the performance of required inspections.

7.5.1 Calibration System Requirements—The manufacturer shall maintain a calibration system for all measuring and test equipment (M & TE) in accordance with MIL-STD-45662 with traceability to the National Institute of Standards and Technology (NIST).

7.5.1.1 Accuracy of the M & TE used to measure allowable variables during testing shall be within one third of the tolerances permitted (see 7.6).

7.6 Test Conditions—Unless otherwise specified in the test, the following tolerances shall be used to control conditions of the tests specified in the Annex:

7.6.1 Ambient Conditions—When ambient is specified, standard ambient conditions shall be maintained at 25 ± 10°C (77 ± 18°F).

7.6.2 Pressure—Unless otherwise specified, the tolerance for the internal pressure applied to the test specimen during testing shall be maintained at ±5%.

7.6.3 Test Fluids—Unless otherwise specified, the test fluids used in the testing of MAF shall include those fluids specified within the test. Water and other fluids such as SAE Grade 10W, MIL-H-5606, MIL-L-7808, or MIL-H-83282 may be used without affecting the validity of the test.

7.6.4 Temperature—Unless otherwise specified, the allowable tolerance for temperature applied to the test specimen during testing shall be ±5°C (±10°F).

7.7 Pass or Fail Criteria—Pass or fail criteria for each test shall be based upon meeting or exceeding the performance requirements specified in each test.

8. Dimensions

8.1 MAF Dimensions:

8.1.1 Type I MAF dimensions shall be as specified by the manufacturer.

8.1.2 Types II and III MAF dimensions shall be as specified in MIL-F-18866 or SAE J514 or as agreed to between the manufacturer and the purchaser.

8.1.3 Type IV MAF dimensions shall be as specified by the manufacturer.

8.1.4 Type V MAF dimensions shall be as specified by the manufacturer.

8.1.5 Type VI MAF dimensions shall be as specified by the manufacturer.

9. Workmanship, Finish, and Appearance

9.1 Machined Surfaces—Machined surfaces shall be free from burrs, cracks, laps, or seams which would affect the suitability for the intended service.

9.1.1 All machined surfaces shall be 3.2-µm roughness, average (Rₐ) (125-µin. Rₐ) as specified in ANSI B46.1 or duplicate of that qualified.

9.1.1.1 External surfaces that do not affect the overall function of MAFs shall be excluded from the requirement specified in 9.1.1.

9.2 Unmachined Surfaces—Unmachined surfaces, such as forging or casting surfaces and bar stock flats, shall be free from scale, blisters, fins, folds, seams, laps, segregations, or cracks which may be injurious to personnel or equipment or affect MAF performance.

10. Sampling for Testing

10.1 Inspection Sampling of Raw Material—Except when specified herein, the number of samples required for inspection of raw materials for conformance of products during manufacturing and processing shall be in accordance with established quality assurance procedures maintained by the manufacturer and approved by the purchaser.

10.2 In-Process Inspection Sampling of MAFs—Inspection sampling plans of MAFs being manufactured or processed shall be mutually agreed upon between the manufacturer and the purchaser. MIL-STD-105 shall be used when specified in the purchase order or contract. Level of inspection and acceptable quality level (AQL) shall be in accordance with the manufacturer’s quality assurance procedures.

10.3 Lot Acceptance—Lot acceptance sampling plans shall be mutually agreed upon between the manufacturer and the purchaser. MIL-STD-105 shall be used when specified in the purchase order or contract.

10.4 Sampling for Inspection of Type III Ferrules—A random sample of ferrules shall be selected from each lot in accordance with MIL-STD-105, Special Inspection Level S-2, AQL of 2.5, and tested in accordance with 13.4.1. Other inspection or sampling plans may be used upon mutual agreement between the manufacturer and the purchaser.

10.4.1 A minimum of five ferrules shall be randomly selected from each lot and subjected to the testing specified in 13.4.2.

10.5 Sampling for Inspection of Fabricated MAFs—A minimum of four samples shall be selected at random from each lot of welded products and subjected to the tests specified in 13.4.3.

11. Number of Tests and Retests

11.1 Number of Test Specimens—The tests used to qualify MAFs and the number of specimens required for each test shall be as specified in Table 3.

11.2 Replacement of Test Specimens—When untested specimens are rejected as a result of overtightening, inferior workmanship or materials, or assembly, the specimens shall be dispositioned in accordance with the manufacturer’s quality assurance procedures.
11.2.1 The original unique numbers assigned in accordance with 12.3.1 shall be recorded in the test report along with the reason for rejection.

11.2.1.1 New test specimens with MAFs of the same type, grade, and class, and pipe or tube of the same outside diameter and wall thickness shall be prepared in accordance with Section 12.

11.3 Penalty Runs—In the event of a test failure, the manufacturer shall proceed with one of the following options:

11.3.1 If the failure is determined to be design related, the manufacturer shall redesign the MAF and start all tests from the beginning. The requirements in 11.3.2 shall not apply to redesigned MAF.

11.3.2 If the failure is determined to be unrelated to the design, the test specimen shall be rerun. A replacement test specimen shall be prepared in accordance with the requirements in 11.2 and Section 12.

11.3.3 If the failure cannot be determined to be either design related or not design related, the manufacturer shall test three additional penalty specimens. The requirements specified in 11.3.2 shall apply.

11.4 Penalty Run Specimen Preparation—Penalty run specimens shall be prepared when MAF has failed any of the tests specified in the Annexes.

11.4.1 The MAF used for penalty runs shall be of the same type, grade, and class as the failed MAF being replaced.

11.4.2 The pipe or tube used in penalty runs shall be of the same material (including form and condition), outer diameter, and wall thicknesses as the pipe or tube being replaced.

11.4.3 Preparation of the penalty run specimens shall be in accordance with Section 12.

11.4.4 Penalty run specimens shall be identified in accordance with 12.3 and 11.4.5.

11.4.5 In addition to the part number and test specimen number, a designator shall be placed after the test specimen number which would allow the specimen to be identified as a penalty run specimen. The method used to identify penalty run specimens shall be at the manufacturer’s option.

12. Specimen Preparation

12.1 Specimen preparation and installation of MAFs on appropriate testing apparatus shall be in accordance with the manufacturer’s recommended procedures.

12.1.1 Permanent MAFs shall be assembled at the minimum allowable insertion depth permitted by the manufacturer’s recommended procedure.

12.1.2 Separable MAFs shall be assembled using the minimum value (that is, torque, nut rotation, and so forth) permitted by the manufacturer’s recommended procedure.

12.2 Assembly of Specimens—MAFs qualified under the requirements of this specification shall be tested and qualified as a completed assembly. The acceptance of similar, but different, MAF designs shall not permit the intermixing of their subcomponents such as sleeves, nuts, and ferrules.

12.2.1 Test specimens used in testing shall be assembled using a MAF of a single type, grade (or combination of grades), and pipe or tube material.

12.2.2 The wall thickness and outer diameter size of the pipe or tube shall be selected in accordance with the MAF sizes (see 7.3.4) being qualified.

12.2.3 The test specimens shall be assembled using the specimen geometry specified in Fig. 1.

12.3 Identification of Test Specimens—Each test specimen shall be identified with a unique number to provide traceability back to the test records.

12.3.1 Identification of test specimens shall be permanent. In those cases in which size or design does not permit permanent markings, tagging or bagging may be used.

12.3.2 When, as a result of testing, a test specimen is sectioned into two or more pieces, the identification method shall be as specified in 12.3.1.

13. Test Methods

13.1 Standard Qualification Tests—All tests used to qualify MAFs shall be as specified in the Annexes. The following primary tests are described:

<table>
<thead>
<tr>
<th>Name of Test</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Tests for MAFs</td>
<td>A1</td>
</tr>
<tr>
<td>Examination of Specimen</td>
<td>A2</td>
</tr>
<tr>
<td>Pneumatic Proof Test</td>
<td>A3</td>
</tr>
<tr>
<td>Hydrostatic Proof Test</td>
<td>A4</td>
</tr>
<tr>
<td>Impulse Test</td>
<td>A5</td>
</tr>
<tr>
<td>Flexure Fatigue Test</td>
<td>A6</td>
</tr>
<tr>
<td>Tensile Test</td>
<td>A7</td>
</tr>
<tr>
<td>Hydrostatic Burst Test</td>
<td>A8</td>
</tr>
<tr>
<td>Repeated Assembly Test</td>
<td>A9</td>
</tr>
<tr>
<td>Rotary Flexure Test</td>
<td>A10</td>
</tr>
<tr>
<td>Mercurous Nitrate Test</td>
<td>A11</td>
</tr>
</tbody>
</table>

FIG. 1A

FIG. 1B

FIG. 1C

CAPPED END WITH PORT (2 PLACES TP)  TENSILE SPECIMENS DO NOT REQUIRE CAPPED ENDS  MAF TEST SPECIMEN  STAIN CASE LOCATED ON THE HIGH STRESS SIDE OF THE PIPE/TUBE 4.8 MM (0.18 IN.) FROM MAF (2 PLACES) (AS REQUIRED)  PIPE TEST SPECIMENS SHALL BE A MINIMUM OF TEN TIMES (10X) PIPE/TUBE O.D. VERIFICATION TEST SPECIMEN LENGTH SHALL BE AS SPECIFIED IN TABLE 5B. SPECIMEN GEOMETRY SHALL BE AS SHOWN IN FIGURE 5B.  FREE PIPE/TUBE LENGTH MIN. FIVE TIMES (5X) PIPE/TUBE O.D.

FIG. 1 Typical Specimen Geometries
13.2 Supplementary Tests—When one or more of the supplementary requirements are requested by the purchaser (see 1.2), the following applicable test(s) shall also be performed:

<table>
<thead>
<tr>
<th>Name of Test</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Requirements</td>
<td>S1</td>
</tr>
<tr>
<td>Thermal Cycling Test</td>
<td>S2</td>
</tr>
<tr>
<td>Elevated Temperature Soak Test</td>
<td>S3</td>
</tr>
<tr>
<td>Stress Corrosion Test</td>
<td>S4</td>
</tr>
<tr>
<td>Torsion Test</td>
<td>S5</td>
</tr>
<tr>
<td>Shock Test</td>
<td>S6</td>
</tr>
<tr>
<td>Fire Test</td>
<td>S7</td>
</tr>
<tr>
<td>Vibration Test</td>
<td>S8</td>
</tr>
</tbody>
</table>

13.3 Certification of Test Results—If certified test results are required, a certification shall be provided to the purchaser as specified in the contract or purchase order.

13.4 In-Process Inspection Tests—The following tests shall be performed by the manufacturer in accordance with in-house practices and when specified in the contract or purchase order:

13.4.1 Metallographically prepare, microexamine, and test for hardness and microstructural conformance to the manufacturer’s appropriate specification a random sample of Type III ferrules, as specified in 10.4.1. An appropriate specification is defined as the documented procedures that the manufacturer uses on a continuing basis to produce ferrules. Such ferrules shall be of the same quality as those used in the assemblies that were previously tested and found to satisfy the performance requirements of this specification.

13.4.2 Randomly select a minimum of five Type III ferrules from each lot as specified in 10.5 and test for cut bite quality.

13.4.2.1 Preset the Type III ferrules onto tubing as specified in 13.4.2.2. After disassembly, drive back each ferrule to expose the ring cut for examination. The cut bite shall completely encircle the periphery of the tube. The cut bite shall be clean, smooth, and uniform. A jagged irregular cut bite is unacceptable. There shall be no longitudinal or circumferential cracks on the ferrule before driving it back.

13.4.2.2 Use Type 304 tubing in accordance with Specifications A 213/A 213M, A 249/A 249M, or A 269 for testing corrosion-resistant steel MAFs. Use SAE 1010 tubing to test carbon steel MAFs. The tubing materials as specified will assure consistent results of testing. Preset Type III ferrules onto the tubing in accordance with the manufacturer’s recommended procedures using either a presetting machine, presetting tool, or the MAF.

13.4.2.3 When the Type III ferrules are manufactured from materials other than those specified in 13.4.2.2, conduct the test using tubing material as recommended by the manufacturer.

13.4.3 Fracture test a minimum of four MAFs selected at random from each lot of welded MAFs as specified in 13.4.3.1 and then either crush test in accordance with 13.4.3.2 or macroexamine in accordance with 13.4.3.3.

13.4.3.1 Test two MAFs. Cut each MAF into two or more sections. Cut the sections so that the weld is perpendicular to the longitudinal axis of the section. The total width of the sections taken from each MAF shall be equal to or exceed one fourth of the circumference of the MAF. Remove all weld flashing. Load each section laterally in such a way that the root of the weld is in tension. Bend the section until it fractures or is bent 90°. If the specimen fractures, the fractured surface shall show no evidence of preexisting cracks or incomplete fusion, and the sum of the lengths of inclusions and porosity visible on the fractured surface shall not exceed 10 % of the total area. Cracking or tearing of the parent material is acceptable.

13.4.3.2 Two MAFs shall be tested. Remove all weld flashing. Position each MAF between two parallel plates in a manual or hydraulic press, or between the jaws of a multiple-jaw hydraulic press. The weld shall be located 3.2 mm (½ in.) from the face of the plates or jaws. Flatten the MAF against itself between the parallel plates or crush the MAF to within 50 % of its original diameter between the multiple jaws. There shall be no indication of cracking or tearing in the weld joints. Cracking or tearing of parent material is acceptable.

13.4.3.3 Test two MAFs. Take a cross section of the weld from each MAF. Smooth and etch one face of each cross section to give a clear definition of the weld metal and heat-affected zone. When examined, the weld and the heat-affected zone shall show complete fusion and freedom from cracks.

14. Inspection

14.1 Terms of Inspection—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements (examination and tests) specified herein.

14.2 Raw Material Inspection—Each lot of raw material used to produce MAFs in accordance with this specification shall be inspected for conformance to the applicable material specification. A lot of raw material shall consist of bars, pipe, tube, forgings, or castings of the same heat, produced at essentially the same time and submitted for inspection at the same time.

14.3 Quality Conformance Inspection—MAFs shall be visually and dimensionally examined to verify compliance with the appropriate drawings. Quality conformance inspection shall be performed on each lot of MAFs produced under this specification.

14.3.1 The inspection lot of MAFs shall include MAFs of the same size and shape manufactured under essentially the same conditions from the same lot of material and submitted for inspection at one time.

14.4 Process Control Inspection—MAFs shall be inspected throughout the entire manufacturing and processing cycle. Methods of inspection shall be in compliance with the manufacturer’s quality assurance procedures.

14.5 Inspection Records—Inspection records shall be maintained by the manufacturer. The length of time on file shall be in accordance with the manufacturer’s quality assurance procedures.

14.6 Performance Testing Records—The manufacturer shall maintain a record of all performance tests throughout the life of the MAF design.

14.6.1 The original test specimens, as well as replacement or penalty run specimens, used in performance testing to meet qualification shall be maintained by the manufacturer for a minimum of two years.
14.6.2 Inspection records relating to the performance tests shall be maintained in accordance with 14.5.

15. Certification

15.1 Certification of Testing or Inspection—When requested by the purchaser, the manufacturer shall supply written certifications that the MAF has been tested and qualified in accordance with this specification.

15.2 Certification of Raw Material—A certificate of compliance or mill certificate shall be obtained from the material supplier. This certificate shall state that all applicable requirements of the raw material are met. As a minimum, the material specification shall specify the chemical and mechanical requirements of the material.

16. Product Marking

16.1 Product Marking—Each MAF shall be marked with the manufacturer’s name or trademark, size, and material (material marking is not required for Type V MAF). When shape or size does not permit inclusion of all required markings, the information may be omitted in the reverse order presented.

16.1.1 When MAFs are comprised of multiple components that are assembled, the marking methods used to identify the assembly (and each of its components) shall be as agreed to between the manufacturer and the purchaser.

16.2 Additional Markings—When specified in the contract or purchaser order, additional markings other than those specified shall be applied.

17. Keywords

17.1 axially swaged; bite-type; elastic strain preload (esp); fittings; flared; flareless; grip type; mechanically attached fittings (MAFs); piping; radially swaged; shape memory alloy (SMA); tubing

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in part or whole by the purchaser in the contract or purchase order.

S1. GENERAL REQUIREMENTS

S1.1 Scope

S1.1.1 This section covers the general requirements that, unless otherwise specified, apply to the Annex or this section whenever invoked individually or collectively by the purchaser of MAFs in the contract or purchase order. The testing requirements specified herein are applicable to all the tests described in Sections S2 through S8 (see Table S1.1). The requirements covered herein are outlined as follows:

S1.3 Testing Requirements
S1.4 Quality Assurance Requirements
S1.5 Product Marking Requirements

<table>
<thead>
<tr>
<th>TABLE S1.1 Supplementary Tests</th>
<th>Description of Test</th>
<th>Number of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examination of specimen (Annex A2)</td>
<td>40 specimens</td>
<td></td>
</tr>
<tr>
<td>Pneumatic proof test (Annex A3)</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Hydrostatic proof test (Annex A4)</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Thermal cycling test (S2)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Elevated temperature soak test (S3)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Stress-corrosion test (S4)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Torsion test (S5)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Shock test (S6)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Fire test (S7)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Vibration test</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

S1.1.2 Cadmium plating shall not be used on MAFs intended for use on U.S. Navy vessels.

S1.1.3 This section is applicable to MAFs that are designed for the following pipe or tube sizes:

S1.1.3.1 This supplementary section is applicable to MAFs suitable for pipe outside diameters for NPS 3.2 mm ( 1⁄8 in.) through 63.5 mm (2 1⁄2 in.).

S1.1.3.2 This supplementary section is applicable to MAFs suitable for tube outside diameters from 6.4 mm (0.250 in.) to 73.0 mm (2.875 in.).

S1.1.3.3 Other pipe or tube sizes, with supporting data, may be submitted to the purchaser for evaluation and approval.

S1.1.4 The following supplementary tests listed herein are as follows:

<table>
<thead>
<tr>
<th>Test</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Cycling Test</td>
<td>S2</td>
</tr>
<tr>
<td>Elevated Temperature Soak Test</td>
<td>S3</td>
</tr>
<tr>
<td>Stress-Corrosion Test</td>
<td>S4</td>
</tr>
<tr>
<td>Torsion Test</td>
<td>S5</td>
</tr>
<tr>
<td>Shock Test</td>
<td>S6</td>
</tr>
<tr>
<td>Fire Test</td>
<td>S7</td>
</tr>
<tr>
<td>Vibration Test</td>
<td>S8</td>
</tr>
</tbody>
</table>

S1.1.5 The sections listed below from the main body of this specification apply to the test specimens used to perform the tests specified in S1.5 (see S1.8). MAFs shall have met the requirements of Annex A1 and Annex A2 before performing any test, unless otherwise specified herein.

<table>
<thead>
<tr>
<th>Title</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>1</td>
</tr>
<tr>
<td>Referenced Documents</td>
<td>2</td>
</tr>
<tr>
<td>Terminology</td>
<td>3</td>
</tr>
</tbody>
</table>
S1.1.6 Unless otherwise specified, the requirements specified in the main body and Annex A1 and Annex A2 of this specification shall apply.

S1.1.6.1 In the event of a conflict between this supplement and the requirements specified in the main body of this specification and Annex A1 and Annex A2, or both, the requirements specified herein shall take precedence, unless otherwise invoked in the contract or purchase order by the purchaser.

S1.1.7 Before beginning performance testing, the manufacturer shall obtain approval from the purchaser of the test plan to be used. The plan shall include the following information:

S1.1.7.1 A matrix showing the MAF grade(s) (or different combination(s) of grades) (see 4.2) and MAF class(es) (see 4.3) to be qualified,

S1.1.7.2 MAF sizes selected to qualify every size within its range (see S1.1.3),

S1.1.7.3 Compatible pipe or tube materials to be in assembly with the MAFs to be tested (see Table S1.2),

S1.1.7.4 Pipe or tube wall thicknesses and sizes selected to qualify the pipe or tube throughout its range (see S7.3.5),

S1.1.7.5 The manufacturer’s recommended procedure covering the assembly of the MAFs onto pipe or tube (see 12.1), and

S1.1.7.6 Test fluids used for each test (see S7.6.3).

S1.1.8 After verification, the purchaser shall approve the matrix or specify any additional tests required for each MAF family for the manufacturer to include in the program.

S1.2 Significance and Use

S1.2.1 The significance of this section allows the purchaser of MAFs to invoke those general, testing, or quality assurance requirements individually or collectively to meet their existing requirements. The purchaser may use this section as a guide to make out an agreement with the manufacturer to fulfill their requirements for MAFs.

**TABLE S1.2 Pipe or Tube Material, Size, and Tolerances**

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Material Specification</th>
<th>Material Size</th>
<th>Material Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>MIL-P-24691/1</td>
<td>ANSI B36.10</td>
<td>A 530/A 530M</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>MIL-P-24691/3</td>
<td>ANSI B36.10</td>
<td>A 530/A 530M</td>
</tr>
<tr>
<td>Copper-nickel</td>
<td>MIL-T-8606</td>
<td>AND 10102</td>
<td>MS 33531</td>
</tr>
<tr>
<td>Nickel-copper</td>
<td>MIL-T-16420</td>
<td>MIL-T-16420</td>
<td>MIL-T-16420</td>
</tr>
<tr>
<td>Copper</td>
<td>MIL-T-24107</td>
<td>MIL-T-24107</td>
<td>B 251</td>
</tr>
</tbody>
</table>

S1.3 Testing Requirements

S1.3.1 MAF test specimens shall be selected for qualification in accordance with the requirements specified herein and in 7.3.

S1.3.1.1 Each and every pipe or tube size (both outside diameter and wall thickness) and each and every material combination of both pipe or tube (including annealed and drawn conditions) and MAFs may be qualified in accordance with this specification. If the manufacturer can demonstrate by parametric or test data that some tests are not necessary, the purchaser may exempt the manufacturer from the test requirement on a case-by-case basis.

S1.3.2 The test MAFs shall be of the same base material as the pipe or tube. Other combinations of materials, approved for use by the purchaser, must be shown to be galvanically compatible, or in accordance with MIL-STD-889.

S1.3.2.1 MAFs shall be shown to meet the requirements of this specification over the full range of pipe or tube tolerances (see S1.3.3.1) either experimentally or by parametric.

S1.3.3 Pipe or tube materials used with MAFs shall conform to the specifications listed in Table S1.1.

S1.3.3.1 Pipe or tube tolerances shall be in accordance with the requirements specified in Table S1.2.

S1.3.3.2 In no case shall the pipe or tube used for testing be machined or otherwise changed from its original mechanical or chemical properties unless otherwise specified in the manufacturer’s installation instructions.

S1.3.3.3 The cut pipe or tube ends may be deburred, but not tapered or otherwise reduced, below the minimum wall thickness.

S1.3.4 Strain gages (as required) shall be placed at a distance not to exceed 4.6 mm (0.18 in.) from the end(s) of the MAF pipe or tube joint (see Fig. 1).

S1.3.5 The test specimens shall be marked using the same methods which will be applied to MAFs sold subsequent to qualification.

S1.3.5.1 All test specimens shall be identified in accordance with the requirements specified in 12.3.

S1.3.6 A test specimen shall consist of one or several pipe(s) or tube(s) joined to MAFs.

S1.3.6.1 MAFs installed on the test apparatus shall be in accordance with the manufacturer’s recommended procedures as approved by the purchaser. No other means of joining the test connector to the pipe shall be permitted.

S1.3.6.2 Unless otherwise specified in the individual test, (see S7) the specimen geometry (Fig. 1) shall be no less than five pipe or tube diameters (outside diameter) long on the end of the MAFs being tested.

S1.3.6.3 After approval of the test plan (see S1.1.7), the test specimens shall be assembled in accordance with the requirements specified in 12.2.

S1.3.7 The minimum amount of specimens required for each supplementary test shall be as specified in Table S1.1 (see S1.3.8). A family of MAFs shall consist of a manufacturer’s single combination of: pressure rating (class), design (type), and material (grade) including form and condition. A family requires tests as follows:
S1.3.7.1 Test each MAF shape. Shapes may be test exempted only if it can be shown to the purchaser’s satisfaction that they are equivalent to those shapes tested.

S1.3.7.2 Test the range of MAF sizes, including the smallest and largest. Test one or more intermediate sizes if the ratio of the minimum to the maximum pipe or tube outside diameter to be tested is equal to or more than ten.

S1.3.7.3 Any nonproportional MAF sizes shall be tested unless they can be shown parametrically to be equivalent to the sizes tested.

S1.3.7.4 Test each pipe or tube material for all material conditions of intended use (that is, annealed and drawn).

S1.3.7.5 For each pipe or tube size being tested, test the minimum and maximum nominal wall thickness of pipe or tube materials selected from Table S1.2.

S1.3.8 A minimum of 60 specimens shall be prepared to cover the unique combinations of a MAF family (see S1.3.7). Each primary test shall have a minimum of five specimens representing all of the unique combinations of a MAF family. When the total amount of specimens (including Annex) is below 60, additional specimens shall be added to attain the minimum of 60 total specimens for all tests (see S1.3.8.5).

S1.3.8.1 The total number of test assemblies must each pass their designated tests successfully to meet the requirements of this performance specification.

S1.3.8.2 The proposed test plan covering unique combinations of test assemblies used in qualification testing shall be submitted to the purchaser for approval (see S1.1.7).

S1.3.8.3 The pneumatic test (see Annex A3), the hydrostatic test (see Annex A4), and the hydrostatic burst test (see Annex A8) (when performed separately or in combination before or after another primary test) are not to be used as a part of the total specimens used for testing because they are connected with the pass and fail criteria of the primary test. In all instances, they are considered to be a part of the primary test and not a separate mechanical test for this calculation.

S1.3.8.4 Also, comparison tests of pipe or tube without MAFs do not count as part of these totals.

S1.3.8.5 Specimens may be reused for other primary tests as long as all of the requirements herein are complied with for each test (see S1.1.7).

S1.3.9 In the event of a test failure, the manufacturer shall proceed in accordance with 11.3.

S1.3.10 At the option of the purchaser, the test laboratory shall cut open or otherwise prepare specimens for detailed examination following any failure.

S1.3.11 Unless otherwise specified within the test, the conditions for testing shall be as specified in 7.6 and as follows:

S1.3.11.1 Unless otherwise specified by the purchaser, the pressures applied during testing shall be calculated based upon the class (rated pressure) assigned by the manufacturer in the test plan (see 4.3). The purchaser may also designate a class not specified in 4.3 to fulfill end-system requirements (see 3.1.1).

S1.3.11.2 The test temperature shall be maintained to within ±5°C (±10°F), unless otherwise specified by the purchaser (see Table S1.3). The test temperature is maintained when the test specimen attains the temperature designated by the test. The temperature shall be stabilized for a period of 1 h or more.

S1.3.12 All testing shall be done at a test laboratory acceptable to the purchaser. The test laboratory shall verify that specimens to be tested are as identified and certify results.

S1.3.12.1 The test laboratory must establish a mutually convenient testing schedule when the purchaser specifies that a witness is to be present during testing.

S1.3.13 Unless otherwise specified, the test report shall contain the following information:

S1.3.13.1 Identification number, a description of each specimen, and the fabrication process.

S1.3.13.2 Description of the test apparatus including instrumentation and their settings during the test.

S1.3.13.3 Photographs of test setup including specimen.

S1.3.13.4 Graphical printout of all data for those tests that record a waveform (if requested by the purchaser).

S1.3.13.5 Leakage rate during testing, if any.

S1.3.13.6 Video tape(s) (fire test only).\(^{c}\)

S1.3.13.7 A record of any unusual observations during testing.

S1.3.13.8 Summary of test results, including but not limited to the following data in tabular form:

1. A description of the specimen shape, pressure rating, material, and method of fabrication,

2. Nominal size, actual pipe outside diameter, actual MAF inside diameter,

3. Pipe material (condition and form), class, and wall thickness,

4. Pressure and temperature, or both, applied during and at the completion of testing,

5. Number of cycles or time at specific atmospheric conditions.

6. Reason for termination of any test,

7. Hydrostatic leakage rate and description, (if any),

8. Summary of pass or fail results, and

9. Calculations (only when requested) to support test data submitted in the test report.

S1.4 Quality Assurance Requirements

S1.4.1 Mill Certification—When specified in the contract or purchase order, a mill certification shall be obtained from the

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**TABLE S1.3 Test Temperatures**

<table>
<thead>
<tr>
<th>Test</th>
<th>Low Temperature</th>
<th>Ambient Temperature</th>
<th>High Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Cycling Test</td>
<td>S2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Cycling (high)</td>
<td>S2.4.1</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Thermal Cycling (low)</td>
<td>S2.4.2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Elevated Temperature Soak</td>
<td>S3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress Corrosion Test</td>
<td>S4</td>
<td>3/1</td>
<td></td>
</tr>
<tr>
<td>Torsion Test</td>
<td>S5</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Shock Test</td>
<td>S6</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Fire Test</td>
<td>S7</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>Vibration Test</td>
<td>S8</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

---

\(^{a}\)The allowable tolerance for all test temperatures is ±5°C (±10°F).

\(^{b}\)The temperatures given correspond to the category and group system temperatures specified in MIL-STD-777.

\(^{c}\)See test procedure for test temperature requirements.
suppliers of all raw materials used in the manufacturing or fabrication of MAFs. The raw material shall be impounded until required testing or verification, or both, is completed. The types of tests used to verify mechanical, chemical, and physical properties shall be at the option of the manufacturer.

S1.5 Product Marking Requirements
S1.5.1 Unless otherwise specified in the contract or purchase order, the rated pressure of MAFs shall be marked in addition to the markings specified in 16.1.1.

S2. THERMAL CYCLING TEST

S2.1 Scope
S2.1.1 Unless otherwise specified, MAFs shall be subjected to a thermal cycling test. The number of specimens used shall be as specified in Table S1.1.

S2.2 Significance and Use
S2.2.1 This test determines the ability of MAFs to withstand changes in temperature while being pressurized to the rated pressure of the MAFs or pipe or tube, whichever is lower. The test is conducted in high temperature and low temperature. This test is used to duplicate conditions that could occur during in-service use.

S2.3 General Testing Requirements
S2.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.
S2.3.2 An equal number of specimens shall be used for high-temperature thermal cycling (see S2.4.1) and low-temperature thermal cycling (see S2.4.2).
S2.3.3 The tests shall be conducted using the temperatures specified in Table S1.3. The specimen may be tested in an environmental chamber held at test temperature.
S2.3.4 The rated test pressure selected for high- and low-temperature thermal cycling shall be as specified in S1.3.11.1.
S2.3.5 The time for the temperature of the test fluid to change from high or low to ambient conditions (and back again) shall be a maximum of 2 min.
S2.3.6 The test specimens shall be monitored continuously for leakage throughout the test.
S2.3.7 If there is any leakage during the thermal cycling tests or subsequent hydrostatic proof tests, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S2.4 Procedure
S2.4.1 High-Temperature Thermal Cycling:
S2.4.1.1 Mount the test specimens in an environment suitable for the conditions stated herein.
S2.4.1.2 The duration of the test shall be three cycles as specified in S2.4.1.4 through S2.4.1.6.
S2.4.1.3 Fill the specimen with fluid (see 7.6.3) and pressurize it to the rated pressure specified in S1.3.11.1. Maintain this pressure throughout the test period.
S2.4.1.4 Increase the specimen temperature to the maximum specified in Table S1.3 within 1 h (see S2.3.5).
S2.4.1.5 Stabilize the specimen at the high temperature and rated pressure for a period of 2 h.
S2.4.1.6 At the conclusion of the high-stabilization period, lower the specimen temperature (while maintaining the rated pressure) to ambient conditions within 1 h and stabilize for an additional 2 h (see S2.3.5).
S2.4.1.7 The steps specified in S2.4.1.4 through S2.4.1.6 constitute one cycle. Repeat these steps until three cycles have been completed (see S2.4.1.2).
S2.4.1.8 After the completion of the third cycle, subject the test specimens to a hydrostatic proof test (see Annex A4).
S2.4.1.9 After completing the hydrostatic proof test, and if there was no leakage during the test period, the specimens have passed the high-temperature cycling test.
S2.4.2 Low-Temperature Cycling Test:
S2.4.2.1 Mount the test specimens in an environment suitable for the conditions stated herein.
S2.4.2.2 The duration of the test shall be three cycles as specified in S2.4.2.4 through S2.4.2.6.
S2.4.2.3 Pressurize the specimen with a fluid that will meet the low-temperature requirements for this test. The fluid shall be maintained at the rated pressure as specified in S1.3.11.1 throughout the test period.
S2.4.2.4 Lower the specimen temperature to the temperature specified in Table S1.3 within 1 h (see S2.3.5).
S2.4.2.5 Stabilize the specimen at the low temperature and rated pressure for a period of 2 h.
S2.4.2.6 At the conclusion of the low-stabilization period, raise the specimen temperature (while maintaining the rated pressure) to ambient conditions within 1 h and stabilize for an additional 2 h (see S2.3.6).
S2.4.2.7 The steps specified in S2.4.2.4 through S2.4.2.6 constitute one cycle and shall be repeated until three cycles have been completed (see S2.4.2.2).
S2.4.2.8 After the completion of the third cycle, subject the test specimens to a hydrostatic proof test (see Annex A4).
S2.4.2.9 After completing the hydrostatic proof test, and if there was no leakage during the test period, the specimens have passed the low-temperature cycling test.
S2.5 Precision and Bias

S2.5.1 The precision of the high- and low-temperature cycling test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the high- and low-temperature cycling test when the M & TE used is calibrated properly.

S3. ELEVATED TEMPERATURE SOAK TEST

S3.1 Scope

S3.1.1 Unless otherwise specified, MAFs shall be subjected to an elevated temperature soak test. The number of specimens used shall be as specified in Table S1.1. A minimum of two passed specimens must be submitted for burst test (see Annex A8).

S3.2 Significance and Use

S3.2.1 This test determines the ability of MAFs to withstand a constant temperature level while pressurized to the rated pressure of the MAFs or pipe or tube, whichever is lower. After 100 h, the specimens are cooled to ambient temperature and subjected to further tests. This test is used to duplicate conditions which could occur during in-service use.

S3.3 General Testing Requirements

S3.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S3.3.2 The tests shall be conducted using the temperatures specified in Table S1.3 for this test.

S3.3.3 The test pressure selected for the elevated temperature soak test shall be as specified in S1.3.11.1.

S3.3.4 The specimen shall be filled with fluid (see 7.6.3) and pressurized to the rated pressure specified in S1.3.11.1. This pressure shall be maintained throughout the test period.

S3.3.5 If there is any leakage during the elevated temperature soak test, or hydrostatic proof or burst tests, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S3.4 Procedure

S3.4.1 Maintain the test specimens at the rated pressure and at the temperatures specified in Table S1.3 for the material being tested, for a minimum of 100 h, in an air environment.

S3.4.2 At the completion of 100 h, air-cool the test specimens to ambient temperature.

S3.4.3 After ambient temperature is attained, subject the test specimens to a hydrostatic proof test as specified in Annex A4.

S3.4.4 Upon completion of the hydrostatic proof test, subject a minimum of two test specimens to a hydrostatic burst test in accordance with the requirements specified in Annex A8.

S3.4.5 The specimens successfully pass when there is no visible evidence of leakage during the elevated temperature soak test or during the hydrostatic proof and burst test.

S3.5 Precision and Bias

S3.5.1 The precision of the elevated temperature soak test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the elevated temperature soak test when the M & TE used is properly calibrated.

S4. STRESS-CORROSION TEST

S4.1 Scope

S4.1.1 Unless otherwise specified, MAFs shall be subjected to a stress-corrosion test. The number of specimens used shall be as specified in Table S1.1.

S4.2 Significance and Use

S4.2.1 This test determines the ability of MAFs to withstand the effects of corrosion while being subjected to a bending stress. Upon completion of 50 h, the specimens are examined and then subjected to a hydrostatic proof test (see Annex A4). This test is used to duplicate conditions that could occur during in-service use.

S4.3 General Testing Requirements

S4.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S4.3.2 The tests shall be conducted using the temperatures specified in Test Method B 117 for this test.

S4.3.3 The performance test pressure selected for the stress-corrosion test shall be as specified in S1.3.11.1.

S4.3.4 A combined axial stress (bending and internal pressure) applied during the test shall be a minimum of two thirds of the yield strength of the pipe or tube materials specified in Table S1.2. The axial stress as a result of the applied internal pressure shall be calculated using the following formula:

\[ S = \frac{Pd^2}{D^2 - d^2} \]

where
- \( S \) = stress,
- \( P \) = pressure,
- \( D \) = outside diameter, and
- \( d \) = inside diameter.
S4.3.4.1 When other materials are used, cite reference used for yield strength values.
S4.3.5 The apparatus shall be equipped with calibrated gages (see 7.5.1) which permit visual readings of the strain being applied. The apparatus shall be designed to shut down in the event that pressure is lost during the period of the test.
S4.3.6 Calibrated strain gages shall be located on the high stress side of the pipe or tube as shown in the geometries in Fig. 1.
S4.3.7 If there is any leakage during the stress-corrosion test or hydrostatic proof test, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S4.4 Procedure
S4.4.1 Install the test specimens in a test fixture which can impose a stress level equivalent to two thirds of the yield strength of the pipe or the tube material less the axial stress as a result of the internal pressure (see S4.3.4).
S4.4.2 Apply bending stress to the MAF and pipe or tube interface. Take and record a strain gage reading.
S4.4.3 Pressurize the test specimen to the rated pressure (see S1.3.11.1).
S4.4.4 With the applied stress locked into place, subject the specimen to the standard salt spray test in accordance with Test Method B 117 for 50 h.
S4.4.5 After testing, subject the test specimen to a hydrostatic proof test (see Annex A4).
S4.4.6 Clean and metallurgically examine the test specimen including sectioning of the MAF and pipe or tube throughout the high-stress area. The following conditions shall be checked and shall not have occurred:
S4.4.6.1 Indication of cracking or pitting of the exposed surfaces of MAF and tubing within one diameter of the MAF greater than that exhibited on the remainder of the tubing when visually examined with 10× power magnification.
S4.4.6.2 Leakage or burst at a value less than the specified test pressure (see S4.4.3).
S4.4.6.3 Indications of inter- or trans-granular stress corrosion paths during metallurgical examination of longitudinal and transverse sections of the MAF and pipe or tube junction.
S4.4.7 The specimens successfully pass this test when they complete the stress-corrosion test without showing any of the indications specified in S4.4.6 and successfully complete the hydrostatic proof test requirements specified in Annex A4.

S4.5 Precision and Bias
S4.5.1 The precision of the stress-corrosion test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the stress-corrosion test when the M & TE used is calibrated properly.

S5. TORSION TEST

S5.1 Scope
S5.1.1 Unless otherwise specified, MAFs shall be subjected to a torsion test. The number of specimens used shall be as specified in Table S1.1.

S5.2 Significance and Use
S5.2.1 This test determines the ability of MAFs to withstand displacement of the MAFs and pipe or tube joint through the application of torque. After creating this displacement between the MAF and the pipe or tube, the test assembly is subjected to a hydrostatic proof test in accordance with the requirements specified in Annex A4. This test is used to simulate environmental conditions that could occur during end-service use.

S5.3 General Testing Requirements
S5.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.
S5.3.2 The tests shall be conducted at ambient temperature as specified in Table S1.3 for this test.
S5.3.3 If there is any leakage during the hydrostatic proof test, the specimen fails and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S5.4 Procedure
S5.4.1 Draw a straight line from end to end on the specimen to be tested.
After tightening, the hydrostatic proof test shall be performed from the beginning without any leakage. If leakage occurs during the secondary test, see S5.3.3.

S5.5 Precision and Bias
S5.5.1 The precision of the torsion test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There may be bias in the results of the torsion test if the line drawn has irregular edges or is too thick or is thick and thin, which may make it difficult to measure the amount of actual displacement.

S6. HIGH IMPACT SHOCK TEST

S6.1 Scope
S6.1.1 Unless otherwise specified, MAFs shall be subjected to a high impact shock test. The number of specimens used shall be as specified in Table S1.1. A minimum of two passed specimens shall be used for burst test (see Annex A8).

S6.2 Significance and Use
S6.2.1 This test verifies the ability of MAFs to withstand a series of impacts while being pressurized to the rated pressure of the MAFs or pipe or tube, whichever is lower. This test is used to duplicate in-service conditions that could occur.

S6.3 General Testing Requirements
S6.3.1 The test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.
S6.3.2 The tests shall be conducted using the temperatures specified in Table S1.3 for this test.
S6.3.3 The rated pressure selected for the high-impact shock test shall be as specified in S1.3.11.1.
S6.3.4 If there is any leakage during the high-impact shock test or subsequent hydrostatic proof test, the specimens fail and the test shall be discontinued at that point. If failure occurs, follow the instructions specified in S1.3.9.

S6.4 Procedure
S6.4.1 Fill each test specimen with fluid in accordance with 7.6.3 before installation onto the shock test fixture.
S6.4.2 Pressurize the test specimens to the rated pressure of the MAF or pipe or tube, whichever is lower (see S1.3.11.1).
S6.4.3 With the test specimen pressurized, subject it to impacts from hammer drop heights of 304.8 mm (1 ft), 914.4 mm (3 ft), and 1524 mm (5 ft). The test criteria shall be in conformance with MIL-S-901 (for Grade A, Class I, Type A, lightweight hull-mounted equipment).
S6.4.4 After completion of high-impact shock test, subject the specimens to a hydrostatic proof test (see Annex A4) followed by a burst test (see Annex A8).
S6.4.5 The test specimens successfully pass high-impact shock testing when they do not show evidence of leakage during the shock test, hydrostatic proof test, and burst test.

S6.5 Precision and Bias
S6.5.1 The precision of the high-impact shock test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the high-impact shock test when the M & TE used is calibrated properly.

S7. FIRE TEST

S7.1 Scope
S7.1.1 Unless otherwise specified, MAFs shall be subjected to a fire test. The amount of specimens required for testing shall be as specified in Table S1.1 (see S1.3.7).
S7.1.2 This test should be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire hazard or the fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire hazard assessment or a fire risk assessment which takes into account all the factors that are pertinent to an assessment of the fire hazard or the fire risk of a particular end use.
S7.1.3 Limitation—This fire test is a part of a set of tests used for evaluating the performance characteristics of MAFs. It is not intended for use independently in part or whole (see 1.7).

NOTE S7.1—High pressures created during this test can result in catastrophic failure of the test specimen. Precautions shall be taken to protect personnel and facilities.

S7.2 Significance and Use
S7.2.1 This test establishes a combined exposure of internal pressure and external heat flux to determine the ability of MAFs to withstand a 30-min simulated fire condition. Heat flux instead of temperature was selected because it is a better measure of fire exposure. The pressure and heat flux exposure specified herein represents a specific fire condition that could occur on board ship. The specified exposure is not sufficient to predict the survival of MAFs during all types and sizes of shipboard fires. After the fire test, MAF specimens are subjected to hydrostatic proof tests. MAFs are graded according to the amount of leakage during the hydrostatic tests. The fire test may be used to determine the acceptability of MAFs for use in fire hazardous areas on board ship where fire conditions such as those caused by a flammable liquid fire could occur.
S7.3 General Testing Requirements

S7.3.1 The test specimens may be pneumatically tested (see Annex A3) and hydrostatically tested with water (see Annex A4) at the option of the manufacturer.

S7.3.2 All testing shall be done at a test laboratory acceptable to the purchaser (see S1.3.12).

S7.3.2.1 The fitting manufacturer must submit advance proof of ability of the independent test laboratory to meet the requirements specified by the purchaser (including: facilities, equipment, personnel, instrumentation, and sample data).

S7.3.3 The fire test laboratory shall verify that specimens to be tested are identified properly, conduct all tests, and certify results.

S7.3.3.1 Fire test laboratory personnel shall witness test specimen installation and provide certification of fabrication in accordance with approved written fabrication techniques and procedures.

S7.3.4 After verification of the unique combinations of the fitting family (see S1.3.7), the purchaser may specify one additional random fire test for each manufacturer to include in its test plan.

S7.3.5 The specimens to be tested shall be assembled in accordance with the geometries shown in Fig. 1, except that the minimum pipe or tube length shall be as specified in S7.4.2.

S7.3.5.1 Connection of each MAF to pipe or tube shall be done using the manufacturer’s approved assembly procedures (see S1.3.6).

S7.3.5.2 The MAFs assembled into fire test specimens shall be the same in all respects as the MAFs subjected to other tests herein and in the Annex.

S7.3.6 Any furnace or other apparatus large enough to expose the minimum length of specimen (see 7.4.2) to the required heat flux may be used.

S7.3.6.1 If an electric furnace is used, a thin coat of flat black paint must be applied to each specimen before the fire test.

S7.3.6.2 Multiple specimens may be tested at the same time if the required heat flux exposure of each specimen is assured.

S7.3.7 Any fuel that achieves the required heat flux may be used.

S7.3.8 Install sufficient total heat-flux gages within a 15–cm (6–in.) radial distance of each specimen centerline to measure a spatial average of the total cold wall heat flux at all exposed surfaces of each specimen during all tests. Alternatively, precalibrate the furnace or other apparatus as specified in S7.3.11.

S7.3.8.1 Measure the required heat flux using circular foil heat-flux gages (often call Gardon gages after the developer). The gage must be calibrated and water cooled and must sense total heat flux (radiant and convective).

NOTE S7.3—Test Methods E 511 and E 1529 describe the design and use of circular foil heat flux gages.

S7.3.9 Furnace thermocouples, if used, are to be fabricated by fusion welding the twisted ends of 1.63-mm (0.064-in.) diameter chromel-alumel wires having a time constant of 2 min or less and mounting the wires in porcelain insulators.

S7.3.9.1 The furnace thermocouple assembly is to be inserted through a standard weight 12.7-mm (½-in.) steel or chrome-nickel alloy pipe. The thermocouple junction is to protrude 12.7 mm (½ in.) from the open end of the pipe.

S7.3.10 Heat flux (or temperature) and pressure shall be monitored continuously and recorded at intervals not exceeding 10 s during the first 5 min and every 30 s thereafter.

S7.3.10.1 Measure the internal pressure of MAF specimens with transducers appropriate to each specimen’s test pressure.

S7.3.11 Instead of continuous heat-flux measurement, the furnace or other apparatus may be calibrated to establish a time-temperature curve that provides the required heat flux to each specimen. The calibrated time-temperature conditions must be measured and successfully reproduced in every subsequent material test. Measure temperature and heat flux and follow:

S7.3.11.1 For each specimen location, measure a spatial average of the total cold wall heat flux that would exist at all exposed surfaces of the longest specimen to be tested in that location. Position the heat-flux gages within a 115–cm (6–in.) radial distance of the specimen centerline.

S7.3.11.2 Measure the heating environment temperature with not less than six furnace thermocouples as specified in S7.3.9 symmetrically distributed at the outer boundaries of, but not in contact with, the test specimen(s). Any cage or other safety barrier must be included in the calibration test.

S7.3.11.3 If the furnace or other apparatus has provision for multiple specimens, calibrate each position with all other positions occupied to assure specimens are not shielded from direct impingement of the required flux.

S7.3.11.4 The furnace or apparatus must be recalibrated each time it is repaired or modified or once per year or every 300 test h, whichever is first.

S7.4 Procedure

S7.4.1 Pressurize and instrument each specimen separately, except that the specimens requiring the same test pressure may be manifolded. When a manifold is used, any leakage invalidates the fire test for all specimens manifolded. See S1.3.9 for further instructions.

S7.4.1.1 Specimens shall be unrestrained at one end to allow for expansion.

S7.4.1.2 Assembly supports shall be beyond the minimum specimen exposure length specified in S7.4.2.

S7.4.2 Expose a fitting with pipe or tube length at each outlet as follows:

S7.4.2.1 If the entire pipe or tube length is exposed to the required heat flux, the minimum length of that pipe or tube shall be three outside diameters.

S7.4.2.2 If any pipe or tube extends beyond the area of required heat flux, the length of the pipe or tube actually exposed to the required heat flux shall be a minimum of ten outside diameters.

S7.4.2.3 Less pipe or tube length may be exposed if screening tests prove that the fitting heats at the same rate with less pipe exposed to the required heat flux.

S7.4.3 The specimen test pressure shall be the rated pressure of the MAF or the temperature-adjusted rated pressure \( P_{\text{TEMP}} \) of the pipe or tube, whichever is lower.
S7.4.3.1 Calculate the temperature-adjusted rated pressure for the appropriate pipe or tube material being tested using the following formula:

\[ P_{\text{TEMP}} = F_s \times \frac{2 \times \sigma_{\text{TEMP}}}{\text{OD}} = \frac{t_{\text{min}} \times \sigma_{\text{TEMP}}}{\text{OD}} \]

where

- \( F_s \) = 0.5 factor of safety,
- \( t_{\text{min}} \) = minimum wall thickness,
- \( \sigma_{\text{TEMP}} \) = temperature-adjusted yield strength of the pipe or tube at 927°C (1700°F) (see S7.4.3.2), and
- \( \text{OD} \) = outside diameter of pipe or tube.

S7.4.3.2 Use the following temperature-adjusted yield strength (\( \sigma_{\text{TEMP}} \)) values for the calculation of \( P_{\text{TEMP}} \) specified in S7.4.3.1:

<table>
<thead>
<tr>
<th>Material</th>
<th>( \sigma_{\text{TEMP}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>14.00 MPa (2.000 ksi)</td>
</tr>
<tr>
<td>CRES (300/300L)</td>
<td>41.00 MPa (6.000 ksi)</td>
</tr>
<tr>
<td>CUNI (70/30)</td>
<td>11.00 MPa (1.600 ksi)</td>
</tr>
<tr>
<td>CUNI (90/10)</td>
<td>8.00 MPa (1.200 ksi)</td>
</tr>
<tr>
<td>Copper</td>
<td>1.00 MPa (0.150 ksi)</td>
</tr>
</tbody>
</table>

S7.4.4 Pressurize the specimens with nitrogen (\( \text{N}_2 \)) or dry air. Control the pressure of the gas as follows:

S7.4.4.1 Before the fire exposure, precharge each specimen with an estimated mass of gas such that after 5 min the total pressure of expanding gas inside the heated specimen will reach 100 ± 10% of the specimen test pressure. Verify there is no leakage.

S7.4.4.2 During the first 5 min of fire exposure, allow specimen pressure to rise uncontrolled up to 110% of the test pressure. If necessary, bleed out gas to maintain 100 ± 10% of the test pressure.

S7.4.4.3 After 5 min of fire exposure, control specimen pressure to maintain 100 ± 5% of the test pressure until 20 min of fire exposure.

S7.4.4.4 After 20 min of fire exposure, close the valves controlling specimen pressure to seal the specimens.

S7.4.4.5 A safety relief valve may be used throughout the fire exposure. If a relief valve is used, the opening pressure setting shall be at least 10% above the test pressure. Instrument the relief valve and record the opening times.

S7.4.4.6 After 20 min of fire exposure, pressure variations within each MAF specimen as a result of variations in specimen gas temperature or specimen volume shall be within ±10% of the specimen test pressure.

S7.4.5 Conduct the fire test in a manner that will allow for a rapid temperature rise to attain the required heat flux.

NOTE S7.4—See Test Method E 1529 for background information on the fire exposure.

S7.4.5.1 The fire exposure shall provide a spatial average total cold wall heat flux of at least 120 kW/m² within 3 min to all exposed surfaces of each specimen and maintain +20 and −0% of that flux throughout the remainder of the test.

S7.4.5.2 Expose each specimen in an environment meeting the fire requirements (see S7.4.5) for 30 min.

S7.4.6 If there is any leakage during the 30-min fire period, the fire test is invalid. See S1.3.9 for further instructions.

S7.4.7 Immediately after completing the fire exposure, allow the test specimens to cool to ambient temperature. Upon attaining room temperature, subject the test specimens to a hydrostatic proof test.

S7.4.7.1 Conduct the hydrostatic proof test in accordance with the requirements specified in Annex A4 except for the following:

1. Fill the specimens with clean fresh water.
2. Pressurize the test specimen to 150% of rated pressure and maintain pressure for at least 30 min.
3. Perform the hydrostatic proof test in the same test laboratory as the fire test.
4. Measure the total accumulated leakage of the hydrostatic proof test.

S7.4.7.2 Total accumulated leakage from the fitting for the duration of the hydrostatic proof test shall be classified with the following grades:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Amount of Leakage, mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-0</td>
<td>0 (None)</td>
</tr>
<tr>
<td>L-10</td>
<td>&gt;0 and &lt;10</td>
</tr>
<tr>
<td>L-50</td>
<td>&gt;10 and &lt;50</td>
</tr>
<tr>
<td>Failure</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

\( ^a \) Total accumulated leakage for the duration of the postfire hydrostatic test.
\( ^a \) Symbol “>” means “greater than.” Symbol “<” means “less than or equal to.”

S7.4.8 The test specimen fails if there is leakage greater than or equal to 50 mL at the fitting joint or within one diameter of the fitting joint during the post-fire or hydrostatic test.

S7.4.8.1 Failure of the pipe away from the fitting does not disqualify a fitting. Failure within one diameter of the fitting constitutes failure of the fitting unless it is shown by tests of pipe alone that the fitting is not likely to have contributed to the pipe failure.

S7.4.9 Complete the test report for the fire test in accordance with S1.3.13.

S7.5 Precision and Bias

S7.5.1 The precision of the fire test is established by the accuracy of the test equipment (see 7.5) and permissible tolerances used during the test. There is no bias when the equipment used is properly calibrated to measure accurate results.
S8. VIBRATION TEST

S8.1 Scope

S8.1.1 When invoked by the purchaser, MAFs shall be subjected to a vibration test. The number of specimens used shall be as specified in Table S1.1.

S8.2 Significance and Use

S8.2.1 This test determines the ability of MAFs to withstand the effects of vibration while being pressurized. After completion of this test, the specimen is subjected to a hydrostatic proof test. This test is used to duplicate conditions that could occur during in-service use.

S8.3 General Testing Requirements

S8.3.1 The test specimen geometry may be in accordance with Fig. 1. The location of strain gages shall be on the high side of the specimen to within 4.6 mm (0.18 in.) as shown in Fig. 1.

S8.3.2 Before beginning the vibration test, the test specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

S8.3.3 The selected specimens shall be filled with fluid in accordance with 7.6.3 before being placed onto the appropriate test fixture.

S8.3.3.1 The test fixture shall be equipped with supports to be attached to the test specimen during testing. The supports shall be spaced as shown in Fig. S8.1. The distance between supports shall be as specified in Table S8.1.

S8.3.4 The testing frequency ranges applied and vibration amplitudes attained shall be recorded in the test report for each of the tests performed.

S8.3.5 The specimens shall show no evidence of leakage during or at the completion of the test.

S8.3.6 At completion of testing, the test specimens shall be subjected to a hydrostatic proof test in accordance with the requirements specified in Annex A4.

S8.3.7 The specimens successfully pass the vibration test after meeting the test requirements herein and passing the subsequent hydrostatic proof test (see Annex A4).

---

**FIG. S8.1 Vibration Test Specimen Geometry**

---

### TABLE S8.1 Distance Between Supports

<table>
<thead>
<tr>
<th>Designation</th>
<th>OD, in.</th>
<th>OD, mm</th>
<th>F, in.</th>
<th>F, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ OD</td>
<td>0.250</td>
<td>6.35</td>
<td>16.4</td>
<td>417</td>
</tr>
<tr>
<td>⅛ OD</td>
<td>0.376</td>
<td>9.53</td>
<td>18.0</td>
<td>457</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>0.405</td>
<td>10.29</td>
<td>18.0</td>
<td>457</td>
</tr>
<tr>
<td>¼ OD</td>
<td>0.500</td>
<td>12.70</td>
<td>19.0</td>
<td>483</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>0.540</td>
<td>13.72</td>
<td>19.0</td>
<td>483</td>
</tr>
<tr>
<td>⅛ OD</td>
<td>0.625</td>
<td>15.89</td>
<td>21.0</td>
<td>533</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>0.675</td>
<td>17.15</td>
<td>21.0</td>
<td>533</td>
</tr>
<tr>
<td>¼ OD</td>
<td>0.750</td>
<td>19.05</td>
<td>23.0</td>
<td>584</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>0.840</td>
<td>21.34</td>
<td>23.0</td>
<td>584</td>
</tr>
<tr>
<td>⅛ OD</td>
<td>1.000</td>
<td>25.40</td>
<td>25.0</td>
<td>635</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>1.050</td>
<td>26.67</td>
<td>25.0</td>
<td>635</td>
</tr>
<tr>
<td>⅛ OD</td>
<td>1.250</td>
<td>31.75</td>
<td>28.0</td>
<td>711</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>1.315</td>
<td>33.40</td>
<td>28.0</td>
<td>711</td>
</tr>
<tr>
<td>¼ OD</td>
<td>1.500</td>
<td>38.10</td>
<td>31.0</td>
<td>787</td>
</tr>
<tr>
<td>¼ NPS</td>
<td>1.560</td>
<td>42.16</td>
<td>31.0</td>
<td>787</td>
</tr>
<tr>
<td>¼ OD</td>
<td>1.900</td>
<td>48.26</td>
<td>34.0</td>
<td>864</td>
</tr>
<tr>
<td>¼ NPS</td>
<td>2.000</td>
<td>50.80</td>
<td>39.0</td>
<td>991</td>
</tr>
<tr>
<td>⅛ NPS</td>
<td>2.375</td>
<td>60.33</td>
<td>39.0</td>
<td>991</td>
</tr>
<tr>
<td>⅛ OD</td>
<td>2.875</td>
<td>73.66</td>
<td>44.0</td>
<td>1118</td>
</tr>
</tbody>
</table>

---

S8.4 Procedure

S8.4.1 Subject MAF to a vibration test in accordance with MIL-STD-167 (Type I: Environmental).

S8.4.2 Conduct the test in each of the three principle directions (X, Y, and Z).

S8.4.3 Conduct and complete testing in one direction before proceeding to the other.

S8.4.4 Pressurize the specimens to 100% of the rated pressure of the pipe or tube or fitting, whichever is lower (see S1.3.11.1).

S8.4.5 The test apparatus shall be able to record any drop in pressure throughout the duration of the test. If pressure is lost at any time during the test and is due to leakage at the MAF joint, the specimens have failed (see S1.3.9).

S8.4.5.1 If there is a loss of pressure through faulty equipment or on the test specimen in any area other than the MAF joint, note this occurrence in the test report, but it is not to be considered as a failure of the MAF.

S8.4.6 Perform the following tests: exploratory vibration test, variable frequency test, and endurance test.

S8.5 Precision and Bias

S8.5.1 The precision of the vibration test is established by the accuracy of the test equipment (7.5.1.1) and permissible tolerances used during the test. There is no bias when the equipment used is calibrated properly to measure accurate results.
A1. PERFORMANCE TESTS FOR MAF

A1.1 Scope

A1.1.1 This section lists the tests to be used to verify whether MAFs meet the performance characteristics of this specification. In addition, any statements that would apply to all tests are specified in this section to minimize redundancy.

A1.1.2 The test procedures appear in the following order:

- Examination of Specimen
- Pneumatic Proof Test
- Hydrostatic Proof Test
- Impulse Test
- Flexure Fatigue Test
- Tensile Test
- Hydrostatic Burst Test
- Repeated Assembly Test
- Rotary Flex Test
- Mercurous Nitrate Test

A1.1.3 The sections of the main body of this specification listed below apply to the test specimens used to perform the tests listed in A1.1.2.

<table>
<thead>
<tr>
<th>Title</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>1</td>
</tr>
<tr>
<td>Referenced Documents</td>
<td>2</td>
</tr>
<tr>
<td>Terminology</td>
<td>3</td>
</tr>
<tr>
<td>Classification</td>
<td>4</td>
</tr>
<tr>
<td>Materials and Manufacture</td>
<td>6</td>
</tr>
<tr>
<td>Performance Requirements</td>
<td>7</td>
</tr>
<tr>
<td>Workmanship, Finish, and Appearance</td>
<td>9</td>
</tr>
<tr>
<td>Number of Tests and Retest</td>
<td>11</td>
</tr>
<tr>
<td>Specimen Preparation</td>
<td>12</td>
</tr>
<tr>
<td>Test Methods</td>
<td>13</td>
</tr>
<tr>
<td>Inspection</td>
<td>14</td>
</tr>
<tr>
<td>Certification</td>
<td>15</td>
</tr>
</tbody>
</table>

A1.2 Significance & Use

A1.2.1 List of All Tests—Section A1.1.3 and Table 1 provide a listing of all tests specified herein. The requirements for each test are as specified in Annex A2-Annex A10.

A1.2.2 General Information—All of the general information which applies to the tests described shall be as specified in A1.3.

A1.3 General Testing Requirements

A1.3.1 The test temperatures shall be as specified in each individual test.

A1.3.2 Tests may be performed by the manufacturer or by a test facility designated by the manufacturer and approved by the purchaser. In all cases, the testing apparatus used to test MAFs shall be calibrated in accordance with the requirements specified in 7.5.1.

A1.3.3 End caps or adapters used to connect the test specimen assembly to the test apparatus, or plugs used to block off a specimen end, shall be an optional design designated by the manufacturer. The end caps or adapters shall be constructed as to prevent their failure during testing.

A1.3.4 Failure of any test specimen which is related to separation or leakage at the joint of the end cap or adapter and pipe or tube shall be recorded in the test report but shall not be considered a failure of the MAF pipe or tube combination being tested. Replacement test specimens shall be prepared in accordance with Section 12.

A1.3.5 Failure of the MAF during testing through causes which are determined to be related to the MAF design shall be dispositioned in accordance with the requirements specified in 11.3.1. When penalty specimens are used, they shall be prepared and identified in accordance with 11.3.2. If the penalty specimens successfully pass all required testing, the initial failure shall be reported but shall not be considered an issue against the approval for technical qualification of the MAF design.

A1.3.6 MAF test specimen(s) shall be assembled in accordance with the manufacturer’s recommended procedures.

A1.3.7 When multiple tests are performed on individual specimens, the sequence of testing shall be as specified in the test description.

A1.3.8 MAFs meet the requirements of this specification after successfully passing all of tests described in Annex A2-Annex A10. When required, the mercurous nitrate test specified in Annex A11 shall also be passed.

A1.4 Precision and Bias

A1.4.1 No statement is made about either the precision or bias of Annex A1, since the result merely states whether there is conformance to the criteria for success specified in the procedure.

A2. EXAMINATION OF SPECIMEN

A2.1 Scope

A2.1.1 This procedure covers the inspection and examination of test specimens prepared in accordance with the requirements specified in Section 12.

A2.2 Significance and Use

A2.2.1 MAFs are attached to and onto pipe(s) or tube(s), or both, using a variety of methods (see 1.1). To ascertain the integrity of each MAF type covered, it becomes important to
subject all types of MAFs to essentially the same tests. When the same tests are used, the assembly of the test specimens becomes critical to the results of each test performed. The usefulness of this procedure lies in the examination of MAF test specimens to ensure that resulting geometries duplicate appropriate stresses on all types of MAFs qualified using the tests specified herein.

A2.3 Procedure

A2.3.1 Assemble MAF test specimens in accordance with the manufacturer’s assembly procedures as approved by the purchaser (see 12.1).

A2.3.2 Inspect the test specimen dimensionally to ensure that it is in compliance with the specimen geometry specified in Fig. 1.

A2.3.3 Inspect strain gauges (when required) to ensure their location on the test specimen as shown in Fig. 1. They shall be calibrated to assure their ability to transmit accurate readings and data to the equipment being used during the appropriate test.

A2.3.4 The materials used to assemble the test specimens shall be in accordance with Section 12. The schedule or the nominal wall thickness of the pipe or tube may vary as recommended by the manufacturer for a single MAF size. This will permit the compatible pipe or tube throughout its given size range to be qualified along with the MAF.

A2.3.5 Quality and workmanship of the test specimens shall be in accordance with the requirements specified in Section 9.

A2.3.6 End caps or adapters used to connect the test specimen to subsequent testing apparatus shall be designed by the manufacturer or its designated testing facility.

A2.3.6.1 MAF specimens prepared for mercurous nitrate testing do not require end caps to be installed.

A2.3.7 During visual examination of the test specimens, record any unusual circumstances in accordance with the requirements specified in 14.6.

A2.3.8 Record the following information in the test report (or form) at the time of examination: date examined, MAF part number, specimen part number, pipe or tube material, outside diameter, wall thickness, and intended use.

A2.4 Precision and Bias

A2.4.1 Precision is based upon the accuracy of the MAF dimensions in accordance with applicable drawings. The pipe or tube used in conjunction with MAF must be in accordance with the raw material specification recommended by the manufacturer. There may be bias for the examination of specimens based upon the human elements involved in the visual inspection methods used.

A3. PNEUMATIC PROOF TESTING (OPTIONAL)\(^\text{16}\)

A3.1 Scope

A3.1.1 This section covers pneumatic proof testing of all MAF test specimens (except mercurous nitrate) as specified in Table 3. All specimens approved for testing shall be subjected to this test.

A3.2 Significance and Use

A3.2.1 This test is the initial test of all MAF specimens prepared for testing. The test is performed by pressurizing the test specimen(s) using dry air or nitrogen (N\(_2\)). The initial pressure of 0.690 MPa (100 psi) is applied. If there is no leakage, the pressure is gradually increased to 125 % rated pressure of the pipe or tube or 3.45 MPa (500 psi), whichever is lower. If the specimen still shows no evidence of leakage after the second pressurization period, the specimen has successfully passed the test. This test is useful in determining if the MAF pipe or tube connection has been assembled correctly or if the MAF design performs as intended at elevated pressure.

A3.3 Procedure

A3.3.1 Place the test specimen in an appropriate chamber and secure it in place in accordance with the manufacturer’s recommended procedures.

---

\(^{16}\) This test is optional as to whether it is performed before all other testing.
bubbles during initial pressurization), the test specimens have passed the pneumatic proof test.

A3.4 Precision and Bias
A3.4.1 The precision of the pneumatic proof test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the pneumatic proof test when the M & TE used is calibrated properly.

A4. HYDROSTATIC PROOF TESTING (OPTIONAL)\(^{16}\)

A4.1 Scope
A4.1.1 This section covers hydrostatic proof testing of selected MAF test specimens (except mercurous nitrate) as specified in Table 3. All specimens prepared for testing shall be subjected to this test.

Note A4.1—Caution: Those specimens selected for fire testing shall be hydrostatically proof tested using water only.

A4.2 Significance and Use
A4.2.1 This test is performed by pressurizing the test specimens using hydraulic fluid or water (see Note A4.1). The initial pressure applied, 0.690 MPa (100 psi), tests the assembled specimen to determine if it can retain fluid without leakage at the pipe or tube and MAF joint. If there is no leakage, the pressure is gradually increased to a second pressurization period of 150 % rated pressure of the pipe or tube or MAF, whichever is lower. This elevated pressure level tests the ability of the specimens to hold fluid without leakage.

A4.2.2 If the specimen still shows no evidence of leakage after the second pressurization period, the specimens have passed the test. This test is useful in determining the integrity of the MAF joint to hold fluid at an elevated pressure without leakage. After successful completion of this test, the test specimens are ready for additional testing.

A4.3 Procedure
A4.3.1 Fill the test specimens with fluid which meets the requirements of 7.6.3 before installation onto the appropriate testing apparatus.

A4.3.2 Place the test specimens in a burst chamber and secure into place in accordance with the manufacturer’s recommended procedures. One end of the test specimen shall be free to move.

A4.3.3 Equip the chamber with calibrated pressure gages (see 7.5.1) to permit visual readings of actual pressure being applied.

A4.3.4 Perform the hydrostatic proof test at ambient temperature.

A4.3.5 Initially pressurize the test specimens to 0.690 MPa (100 psi) ± 5 % for a total period of 5 min. There shall be no evidence of leakage during this 5-min period. If leakage occurs, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 or A1.3.5 for further information.

A4.3.6 If there is no evidence of leakage after the initial 5-min period (see A4.3.5), gradually increase the pressure at an average rate not to exceed 172 MPa/min (25 000 psig/min) to 150 ± 5 % of the rated pressure of the pipe or tube or MAF, whichever is lower. Maintain this pressure for an additional period of 5 min. There shall be no evidence of leakage during this 5-min period. If leakage occurs, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information (as applicable).

A4.3.7 If there is no evidence of leakage within the MAF or MAF joint during both pressurized periods, the test specimens have passed the hydrostatic proof test. The specimens are ready for further testing.

A4.4 Precision and Bias
A4.4.1 The precision of the hydrostatic proof test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the hydrostatic proof test when the M & TE used is calibrated properly.

A5. IMPULSE TESTING

A5.1 Scope
A5.1.1 This section covers impulse testing of selected MAF test specimens. The number of specimens tested shall be as specified in Table 3 using the applicable specimen geometries shown in Fig. 1.

A5.1.1.1 At least 50 % of the separable specimens (Types II, III, and IV) shall be used for repeat assembly testing before testing begins, during the testing period, and after the test is concluded (see Annex A9).

A5.2 Significance and Use
A5.2.1 This test is performed by filling the test specimens with hydraulic fluid or water. The maximum pressure attained during the impulse cycle shall be 133 % of the performance pressure. The specimen is then depressurized to a pressure not greater than 20 ± 5 % of the performance pressure. Each period of pressurization/depressurization is equal to one impulse cycle. The test specimens must be subjected to one million (106) cycles without leakage.
A5.2.2 If the test specimens show no evidence of leakage after completion of the impulse testing, they have passed. If any specimens fail during the course of this test, the test for the failed specimens must be discontinued and the reason for the failure noted in the test report (see A1.3.5).

A5.2.3 All passed specimens shall then be subjected to a hydrostatic proof test as specified in Annex A4. This impulse test is useful to verify the ability of the MAF joint to maintain integrity in the presence of fluctuating system pressure. The occurrences during impulse testing simulate environments that may exist in hydraulic or hydrostatic piping or tubing systems for which MAF is designed.

A5.3 Procedure

A5.3.1 Fill the test specimens with hydraulic fluid which meets the requirements of 7.6.3 before installation onto the appropriate test apparatus.

A5.3.2 Perform the test at ambient conditions throughout the testing period.

A5.3.3 Connect the test specimens onto a testing apparatus that is capable of applying a pressure of 133 ± 5% of the performance pressure of the pipe or tube or MAF, whichever is lower, followed by a depressurization to a pressure not greater than 20 ± 5% of the performance pressure.

A5.3.4 Equip the apparatus with calibrated instruments (see 7.5.1) which permit visual readings of the actual pressures being applied to the specimens throughout the test period.

A5.3.5 Subject the test specimens to impulse pressures at the range specified in A5.3.3. Each application of maximum and minimum pressure shall be equal to one impulse cycle.

A5.3.6 The duration of impulse testing shall be 10⁶ cycles at a rate not to exceed 75 cycles per minute (CPM).

A5.3.7 After the completion of the impulse test, hydrostatically proof test the test specimens in accordance with the requirements specified in Annex A4.

A5.3.8 There shall be no evidence of leakage during impulse testing or hydrostatic proof testing. If leakage occurs during either testing period, discontinue the test. The affected specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A5.3.9 If there is no evidence of leakage at the conclusion of impulse or hydrostatic proof testing, the specimens have passed.

A5.4 Precision and Bias

A5.4.1 The precision of the impulse test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There is no bias in the impulse test when the M & TE used is calibrated properly.

A6. FLEXURE FATIGUE TEST

A6.1 Scope

A6.1.1 This section covers the requirements for flexure fatigue testing of selected test specimens as specified in Table 3. The specimen geometry used shall be as selected from Fig. 1.

A6.1.1.1 At least 50% of the separable specimens (Types II, III, and IV) shall be used for repeat assembly testing specified in Annex A9.

A6.2 Significance and Use

A6.2.1 The significance of this test is to verify the capability of the MAF joint to perform adequately at rated pressure in a flexure environment. The test specimen is subjected to flexure while being pressurized to the maximum rated pressure of the pipe or tube or MAF, whichever is lower. The specimen is subjected to a bidirectional flexure whose plus (+) and minus (−) magnitudes are equal to within 2%. This test is useful in simulating environmental conditions which may exist in fluid systems for which MAF is designed.

A6.2.2 If the specimens do not show signs of leakage, they are subjected to a hydrostatic proof test as specified in Annex A4. The specimen passes when there is no evidence of leakage after the flexure fatigue test and hydrostatic proof test.

A6.3 Procedure

A6.3.1 Fill the test specimens with hydraulic fluid which meets the requirements of 7.6.3 before installation onto the appropriate testing apparatus.

A6.3.2 Equip the apparatus with calibrated gages (see 7.5.1) which permit visual readings of the actual pressures being applied. The apparatus shall be designed to shut down in the event that pressure is lost during the period of the test.

A6.3.3 Locate calibrated strain gages on the high stress side of the pipe or tube as shown in the geometries in Fig. 1. They shall be able to transmit accurate data to calibrated equipment which will be capable of displaying visual data or recording physical data, or both, throughout the period of the test.

A6.3.4 Conduct the test at ambient conditions throughout the testing period.

A6.3.5 Calculate the axial stress introduced as a result of the internal pressure to be applied using the following formula:

\[ S = \frac{Pd^2}{D^2 - d^2} \]

where

\[ S = \text{stress}, \]

\[ P = \text{pressure}, \]

\[ D = \text{outside diameter}, \]

\[ d = \text{inside diameter}. \]
TABLE A6.1 Minimum Combined Total Axial Stress Values

<table>
<thead>
<tr>
<th>Material</th>
<th>Temper</th>
<th>Test Stress Value, ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRES (Type 3XX)</td>
<td></td>
<td>259 MPa (38.00)</td>
</tr>
<tr>
<td>CRES (Type 3XXL)</td>
<td></td>
<td>259 MPa (38.00)</td>
</tr>
<tr>
<td>CuNi (70-30)</td>
<td>annealed</td>
<td>83 MPa (12.00)</td>
</tr>
<tr>
<td>CuNi (90-10)</td>
<td>light drawn</td>
<td>72 MPa (10.50)</td>
</tr>
<tr>
<td>Copper</td>
<td>annealed</td>
<td>93 MPa (13.50)</td>
</tr>
<tr>
<td>Copper</td>
<td>drawn</td>
<td>41 MPa (6.00)</td>
</tr>
<tr>
<td>Carbon steel</td>
<td></td>
<td>152 MPa (22.00)</td>
</tr>
<tr>
<td>Chromium-molybdenium</td>
<td></td>
<td>152 MPa (22.00)</td>
</tr>
</tbody>
</table>

*A total axial stress as a result of combined pressure and bending.*

**A7. TENSILE TEST**

**A7.1 Scope**

A7.1.1 This section covers the requirements for tensile testing selected specimens as specified in Table 3. The number of specimens for this test shall be as specified in Table 3, using the specimen geometries as shown in Fig. 1.

**A7.2 Significance and Use**

A7.2.1 The significance of this test is to apply a tensile load at a controlled separation speed to establish how much load is needed to separate the test specimen. The minimum tensile load occurs during separation of the pipe or tube and MAF joint. The amount of tensile load applied depends upon the cross-section area and the yield strength of the pipe or tube. The formula specified in A7.3.3 constitutes the criterion for the pass or fail requirements of this test. When the minimum tensile load is calculated, the result should be equal to or less than the minimum tensile load required to achieve separation of the specimen joint. Failure occurs when separation takes place at a point before the calculated tensile load is applied. If failure occurs, the test shall be discontinued, and the test report shall be noted with the reason for discontinuing the test.

A7.2.2 The specimens pass this test when the calculated tensile load is achieved without separation of the joint. Movement within the area of the joint is acceptable as long as actual separation does not occur. This test is useful in determining the strength of the pipe or tube or MAF joint. Based upon the strength of the joint, the pipe or tube material and wall thickness can be tailored to withstand failure within the adverse environments present in fluid systems for which MAF is designed.

**A7.3 Procedure**

A7.3.1 Before tensile testing, the specimens may be subjected to a pneumatic test (see Annex A3) and a hydrostatic test (see Annex A4) at the option of the manufacturer.

A7.3.2 Install each test specimen in a constant strain rate tensile machine. The gripping jaws shall be located a minimum of three pipe or tube diameters from the MAF joint.

A7.3.3 The constant strain rate tensile machine shall have the capability to apply a constant tensile load which will result in establishing a speed of approximately 1.3 mm/min (0.05 in./min) at which cross head minimum tensile pull out force (as separation occurs) will be attained. Minimum allowable tensile
load is based upon being equal to or greater than the values stated in the following formula:

\[
\text{Calculated tensile load} = (Kt) \times (Ap) \times (Sy)
\]

where

\[Kt\]  = tensile constant of 1.0;
\[Ap\]  = actual cross-section area of the pipe, mm\(^2\) (in.\(^2\)) based on wall thickness; and
\[Sy\]  = minimum specified yield strength of pipe or tube.

A7.4 Precision and Bias

A7.4.1 The precision for the tensile test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There may be bias in the tensile test when separation occurs at a point other than at the MAF joint. If the pipe or tube were to yield before the MAF pipe or tube joint, this would establish that the pipe or tube is weaker than the MAF. In this case, a stronger yield of pipe or tube may be needed to determine the strength of the joint. In another instance, the MAF may yield before the joint or pipe or tube. If this is the case, reevaluation of the pipe or tube selected may have to be reconsidered to establish the true strength of the MAF joint.

A8. HYDROSTATIC BURST TEST

A8.1 Scope

A8.1.1 This section covers the test requirements for burst testing. The number of specimens to be tested shall be as specified in Table 3.

A8.1.1.1 When the Supplementary Section is invoked, passed specimens from the elevated temperature soak test (S3) and shock test (S6) shall be used instead of new or previously tested specimens from tests specified in the Annex.

A8.2 Significance and Use

A8.2.1 The significance of this test is two-fold. The first significant aspect is the burst test itself. This test verifies the integrity of the pipe or tube and MAF joint to withstand, without leakage or burst, a minimum pressure equal to four times the rated pressure of the pipe or tube or MAF, whichever is lower. To pass this test, the pipe or tube and MAF joint cannot leak or burst below four times the rated pressure.

A8.2.2 The second significant aspect of this test is the test specimens used. All test specimens are comprised of those specimens which have passed other tests as specified in A8.1.1. The use of this test determines whether the MAF design may ultimately receive technical approval for in-service systems by the purchaser.

A8.3 Procedure

A8.3.1 Fill the test specimens with water or hydraulic fluid which meets the requirements of 7.6.3 before installation onto the appropriate testing apparatus.

A8.3.2 Place the test specimens into a burst chamber and secure them into place in accordance with the manufacturer’s recommended procedures. One end must be free to move.

A8.3.3 Equip the chamber with calibrated pressure gages (see 7.5.1) to permit visual readings of actual pressure being applied.

A8.3.4 Perform the hydrostatic burst test at ambient temperature.

A8.3.5 Subject the test specimens to a gradual increase of pressure at an average rate not to exceed 127 MPa/min (25 000 psig/min) to four times the rated pressure of the specimen assembly and hold for a minimum of 1 min. If leakage or burst occurs below four times the rated pressure of the specimen assembly, discontinue the test. The affected test specimens have failed the test. Fill out the test report noting the reason for discontinuing the test. See A1.3.4 and A1.3.5 for further information.

A8.3.6 The test specimens have passed the hydrostatic burst test when four times the rated pressure of the specimen assembly has been attained.

A8.4 Precision and Bias

A8.4.1 The precision of the hydrostatic burst test is established by the accuracy of the measuring and test equipment (M & TE) and their permissible tolerances during the test (see 7.5). There may be bias in this test if the pipe or tube selected burst below four times its rated pressure. If this should occur, the test specimens shall be replaced in accordance with A1.3.4. There may be no bias in this test if the precision of the gages used is the only determining factor. The gages used to apply a gradual increase pressure to a maximum of four times the rated pressure of the specimen assembly, can be read accurately during the test period.
A9.1 Scope

A9.1.1 This section covers the requirements for repeat assembly testing of selected test specimens as specified in Table 3. This test is only applicable to separable MAFs, Types II, III, and IV. Test specimens selected for repeat assembly shall be comprised of at least 50% of the specimens from impulse (see Annex A5) and flexure fatigue (see Annex A6) tests.

A9.2 Significance and Use

A9.2.1 The significance of this test is to verify the integrity of the separable MAF joint to withstand ten repeated assemblies. The disassembly and reassembly shall be performed using the manufacturer’s recommended assembly procedures. The test specimens used for repeat assembly shall be selected from the impulse and flexure tests. An equal amount of specimens shall be selected from each of these tests. Scoring, distortion, damage, or modification of the mating parts of the MAF joint as a result of repeated assembly shall not be cause for failure.

A9.2.2 If the specimens show no evidence of leakage during impulse and flexure testing (or their posttest requirements), they pass the repeat assembly test.

A9.3 Procedure

A9.3.1 Before beginning the impulse or flexure fatigue test, disassemble and reassemble the separable MAF assembly one time.

A9.3.1.1 Each assembly shall have the sealing face rotated by hand 60 to 90° before each reassembly.

A9.3.2 At the conclusion of 25% of the test cycles for impulse and flexure fatigue test, interrupt the test and disassemble and reassemble the test specimens two more times (see A9.3.1.1).

A9.3.3 At the conclusion of 50% of the test cycles for impulse and flexure fatigue test, interrupt the test and disassemble and reassemble the test specimens two more times (see A9.3.1.1).

A9.3.4 At the conclusion of 75% of the test cycles for impulse and flexure fatigue test, interrupt the test and disassemble and reassemble the test specimens two more times (see A9.3.1.1).

A9.3.5 At the conclusion of the impulse and flexure fatigue test (before post testing), disassemble and reassemble the test specimens an additional two times (see A9.3.1.1).

A9.3.6 If the test specimens show no evidence of leakage after the post-test requirements for impulse and flexure fatigue, they have passed the repeated assembly test.

A9.3.7 If the specimens leak any time during the test, discontinue the test. The affected specimens have failed the test. Note the reason for discontinuing the test in the test report. See A1.3.4 and A1.3.5 for further information (as applicable).

A9.4 Precision and Bias

A9.4.1 There is no precision and bias for the repeated assembly test because scoring, distortion, damage, or modification of the sealing surfaces are not causes for failure of this test. The precision and bias statements for subsequent hydrostatic proof, impulse, and flexure fatigue tests apply.

A10. ROTARY FLEX TEST

A10.1 Scope

A10.1.1 When invoked by the purchaser, Types II, III, and IV MAFs shall be subjected to a rotary flex test. This test shall only apply to MAFs with tube diameters of 25.4 mm inclusive (1 in. inclusive) or less. The number of specimens used shall be as specified in Table 3.

A10.2 Significance and Use

A10.2.1 This test determines the ability of separable MAFs to withstand the effects of rotary flex while being pressurized. After completion of this test, the specimen is subjected to a hydrostatic proof test. This test is used to duplicate conditions that could occur during in-service use.

A10.3 General Testing Requirements

A10.3.1 The test specimen geometry shall be in accordance with Fig. 1. The location of strain gages shall be on the high side of the specimen to within 4.6 mm (0.18 in.) as shown.

A10.3.2 Before beginning the test, the specimens may be tested pneumatically (see Annex A3) and hydrostatically (see Annex A4) at the option of the manufacturer.

A10.3.3 The selected specimens shall be filled with fluid in accordance with 7.6.3 before being placed onto the appropriate test fixture.

A10.3.4 The testing frequency ranges applied and amplitudes attained shall be recorded in the test report for each of the tests performed.

A10.3.5 The specimens shall show no evidence of leakage during or at the completion of the test.

A10.3.6 At completion of testing, the test specimen shall be subjected to a hydrostatic proof test in accordance with the requirements specified in Annex A4.

A10.3.7 The specimens successfully pass after meeting the rotary flex test requirements and passing the hydrostatic proof test (see Annex A4).
A10.4 Procedure

A10.4.1 Subject selected separable test specimens to a rotary flexure test. The general test requirements specified in A10.3 apply before beginning the test.

A10.4.2 Fill the specimen with fluid in accordance with 7.6.3, and install the specimen onto the appropriate test apparatus which will allow for a bending moment to be introduced along with the application of pressure (see Fig. A10.1).

A10.4.3 With the specimen unpressurized, a bending moment equivalent to a minimum of 35% of the ultimate tensile strength (of the tubing material) shall be introduced and locked into place. Record the bending moment selected in the test report.

A10.4.4 With the bending moment locked into place, pressurize the specimen to a static pressure of 3.45 MPa (500 psi) minimum. Maintain the bending moment and pressure for the duration of the test.

A10.4.5 Select the amplitude to be used and record it in the test report.

A10.4.6 Flex the specimen in a rotary motion at a minimum of 1750 rpm for a minimum of $10^6$ cycles maintaining the specified bending stress level (see A10.4.3) and pressure (see A10.4.4) at all times.

A10.4.7 The test apparatus shall be able to record any loss of pressure throughout the duration of the test.

A10.4.8 If pressure is lost at any time during the test, the specimen has failed. See A1.3.4 and A1.3.5 for further instructions (as applicable).

A10.4.9 At the conclusion of the rotary flex test, subject the specimens to a hydrostatic proof test (see Annex A4) as specified in A10.3.6. Specimens pass the test upon successfully completing the rotary flex test and the hydrostatic test without any leakage.

A11. MERCURIOUS NITRATE TEST

A11.1 Scope

A11.1.1 This section covers the requirements for conducting a mercurious nitrate test of selected MAF specimens as specified in Table 3. The selection of specimens for this test is restricted to those specimens that are manufactured using either copper-zinc (containing more than 15% zinc) or copper-aluminum alloys.

NOTE A11.1—Warning: All appropriate safety precautions, such as the use of rubber gloves, should be taken while handling and testing with mercury. Care should be taken to prevent mercury contamination of other test specimens.

A11.2 Significance and Use

A11.2.1 The significance of this test is to determine the susceptibility to stress-corrosion cracking of MAFs manufactured from materials specified in A11.1.

A11.3 Procedure

A11.3.1 Use two MAFs from the same material lot from which the specimens are selected to conduct this test.

A11.3.2 Assemble the specimens onto pipe or tube to duplicate the geometries shown in Fig. 1. End caps are not required.

A11.3.3 Immerse the MAF specimen for 30 min in a standard mercurious nitrate solution as specified in Test Method B 154.

A11.3.4 Rinse and dry the MAF before immediate examination. There shall be no cracks.

A11.3.5 MAFs successfully pass this test when no cracks are observed during the examination.

A11.4 Precision and Bias

A11.4.1 The precision of this test is the solution and the material tested. There may be bias if the solution is not properly mixed in accordance with Method B 154.
Standard Specification for
Water Trap for Diesel Exhaust

This standard is issued under the fixed designation F 1431; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the material, dimensions, and construction of diesel exhaust water traps, which shall be required whenever the exhaust is to be expelled through the hull of the vessel.

1.2 The traps are designed to prevent sea backwash from entering the diesel exhaust system.

1.3 The values stated in SI (metric) units shall be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
B 443 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS NO6625) Plate, Sheet, and Strip
F 104 Classification System for Nonmetallic Gasket Materials
2.2 Military Standard:
MIL-S-901 Requirements for Shock Tests, High Impact, Shipboard Machinery, Equipment and Systems
2.3 Other Documents:
American Bureau of Shipping Rules for Building and Classing Steel Vessels
American Welding Society Publication AWS D1.1 Structural Welding Code

3. Ordering Information

3.1 Water traps ordered under this specification shall include the following information:

3.1.1 ASTM designation, title and date of this specification,
3.1.2 Quantity,
3.1.3 Size,
3.1.4 Shock test and grade (see Supplementary Requirement S1),
3.1.5 Handhole shall be at 45° unless otherwise specified, and
3.1.6 Flange dimensions shall be indicated for gaskets.

4. Materials and Manufacture

4.1 Materials:
4.1.1 The tank and baffles shall be of nickel-chromium-molybdenum-columbium alloy and tested in accordance with Specification B 443.
4.1.2 Gaskets—Gaskets shall be ASTM Classification F 104 (F712100–A9B4–E22K5M6) and shall withstand temperatures of 650°C (1200°F).
4.2 Manufacture:
4.2.1 Construction of the water traps shall be in accordance with this specification and Fig. 1.
4.2.2 Welding shall be in accordance with the American Bureau of Shipping Rules for Building and Classing Steel Vessels or the American Welding Society Publication AWS D1.1.

5. Requirements

5.1 Water traps for diesel exhaust systems shall be designed for maximum temperatures of 650°C (1200°F).

5.2 Baffles:
5.2.1 No less than three baffles shall be installed. The bottom baffle shall not extend below the top of the outlet pipe, as shown in Fig. 1.
5.2.2 The inlet may be rotated about the centerline of the trap to suit the installations. The top baffle shall also be rotated to retain the same relation with the inlet as shown in Fig. 1.

5.3 Trap Size:
5.3.1 The trap size shall be a minimum of 1 m (3 ft) high.
5.3.2 The diameter shall equal twice the diameter of the inlet exhaust line.
5.3.3 The minimum free area through the trap shall equal twice the area of the outlet exhaust line.

5.4 Hand Hole—The hand hole shall be configured as indicated in Fig. 1.
6. Dimensions
6.1 The dimensions in Fig. 1 are recommended nominal dimensions.

7. Workmanship, Finish, and Appearance
7.1 Workmanship on traps and piping shall be of sufficient quality to prevent dirt accumulation. Welding shall have small, even beading, free of slag and spatter.
7.2 The trap shall be free of paint.

8. Test Method
8.1 Each trap shall be pneumatically proof tested 35 kPa (5 psi) with no visible seam leakage.

9. Packaging
9.1 The water traps shall be crated or packaged individually for shipment by a commercial common carrier.
9.1.1 Talc and talcum used in the packaging process of items shall be free of asbestos and asbestiform-like materials.

10. Marking
10.1 Each water trap shall bear a weathertight tag showing the purchase order number, ASTM designation, size, and name of manufacturer. The markings on the package shall be approximately 25.4 mm (1 in.) high.

11.1 Source Inspection—The purchaser reserves the right to inspect the manufacturing process and end product in the supplier’s plant.

12. Keywords
12.1 diesel exhaust systems; piping systems
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract order.

S1. Provisions to withstand high shock. The grade will be specified by the navy requirements.

S1.1 When specified, the diesel exhaust water trap shall meet the requirements set forth in MIL-S-901.

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Standard Specification for
Mechanically Refrigerated Shipboard Air Conditioner

This standard is issued under the fixed designation F 1433; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers self-contained mechanically refrigerated air conditioners for shipboard use in air circulation, air cooling, and dehumidification.

1.2 These air conditioners are intended for use in compartments and areas where central system air conditioning is not provided.

1.3 The values stated in SI metric units are to be regarded as standard.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 276 Specification for Stainless Steel Bars and Shapes
A 569/A 569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial
B 16/B 16M Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines
B 61 Specification for Steam or Valve Bronze Castings
B 75 Specification for Seamless Copper Tube
B 148 Specification for Aluminum-Bronze Sand Castings
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
D 3951 Practice for Commercial Packaging

2.2 Air-Conditioning and Refrigeration Institute (ARI):

2.3 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE):

3. Terminology

3.1 Definitions:

3.1.1 inspection—the process of measuring, examining, testing, gaging, or otherwise comparing the unit with the applicable requirements.

3.1.2 lot—all units of the same type, service, and size offered for delivery at one time.

3.2 Definitions of Terms Specific to This Standard:

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

3 Withdrawn.


5 Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.


7 Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.

8 Available from Underwriters Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

9 Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5034, Attn: NPODS.
3.2.1 air discharge plenum—an enclosure (housing) containing guide vanes and a grill or louvers in the outlet opening for directing the airflow.

3.2.2 air handling/evaporator section—an enclosed component consisting of an air filter, fan with drive motor, evaporator (cooling coil), refrigerant flow control, and condensate collector and drain.

3.2.3 condensing unit—contains refrigerating components, consisting of a compressor with a drive motor, condenser, receiver, operating and safety controls, and interconnecting piping and wiring. The controls include a condenser water regulating valve, high and low refrigerant pressure switches, refrigerant relief device, and motor overload protection.

3.2.4 cooling effect—the net room sensible cooling effect of a unit is defined as the difference between the net total cooling effect and the dehumidifying effect, expressed in watts. The net total cooling effect is the total useful capacity of the unit for removing heat from the space to be treated, expressed in watts. The net dehumidifying effect is the difference between the moisture content in kilograms per hour of the entering and leaving air, multiplied by 685, expressed in watts.

4. Classification

4.1 The air conditioners should be of the following types, services, arrangements, and size as specified:

- Type I drip-proof protected
- Type II explosion-proof enclosed
- Service 1 440-V 60-Hz alternating current (ac)
- Service 2 230-V direct current (dc)
- Service 3 115-V dc
- Service 4 220-V 60-Hz alternating current (ac)
- Arrangement A with air discharge plenum
- Arrangement B without air discharge plenum
- Size 2 minimum cooling capacity 7000 W
- Size 3 minimum cooling capacity 10 500 W
- Size 5 minimum cooling capacity 17 500 W
- Size 7½ minimum cooling capacity 26 000 W

5. Ordering Information

5.1 Orders for material under this specification shall include the following:

5.1.1 Title, number, and year of issue of this specification.
5.1.2 Type, service, arrangement, and size of unit (see 4.1).
5.1.3 Air discharge plenum required (see 6.1 and 6.5.10).
5.1.4 Type of power supply for equipment and motors (see 6.5.14.1 and 6.5.14.2).
5.1.5 When drip-proof protected or explosion-proof equipment is required (see 4.1, 6.5.14.1, and 6.5.14.2).
5.1.6 When certification and test reports are required (see 14.1).

6. Materials and Manufacture

6.1 General—Air conditioners covered by this specification shall consist of a condensing unit section, an air handling/evaporator section, and a motor controller. An air discharge plenum may be included, if specified. These air conditioners shall be self-contained and shall perform as specified in this specification when connected to cooling water, drainage, and electric power in accordance with UL 465 and ARI 210. The refrigerant system shall be constructed in accordance with the requirement of ASHRAE 15. Every component, including interconnecting wiring and piping, shall be enclosed within the cabinet, except where external mounting is permitted by this specification. The air conditioner shall be factory assembled, complete, self-contained, with the refrigerant system and components dehydrated and charged with the operating quantities of refrigerant and oil. The air conditioner shall be ready for operation after removal of the shipping protection, opening of valves, adjustment of belts, and connection to services. Valves, controls, and equipment subject to service and repair shall be readily accessible for servicing through removable panels. Where panels are provided for access to equipment, machine screws may be used for fastening.

6.2 Refrigerant System—Every component, including piping, controls, and accessories by the refrigerant system, shall be constructed for use with Refrigerant-22 (monochlorodifluoromethane) or other specified refrigerant.

6.3 Materials—Materials shall be as specified in this specification.

6.3.1 Dangerous Materials—Mercury and materials which may produce dangerous gases or cause other harmful effects under conditions, including fire, shall not be used. Magnesium and its alloys shall not be used in the manufacture of the air conditioners or in any component parts.

6.3.2 Corrosion Protection—Corrosion-resisting steel, copper, brass, bronze, chromium, copper-nickel, and copper-nickel alloys as specified in this specification are considered corrosion-resisting materials. Where corrosion-resisting steel is used, it shall be type 316 or 347 in accordance with Specification A 276. Corrosion-resisting steel, when fabricated by any method that tends to reduce corrosion-resisting properties, shall be normalized to restore those properties before being used in the assembly of any unit.

6.3.2.1 Noncorrosion-Resisting Materials—Noncorrosion-resisting materials are to be protected against corrosion by the use of the chemicals, electrolytic processes, plating, or paints and enamels.

6.3.2.2 Fastenings or Fittings—Bolts, nuts, studs, pins, screws, and such other fastenings or fittings shall be of corrosion-resisting material. Self-tapping screws with machine screw threads may be used in the cabinet assembly. Sheet metal screws with sheet metal threads shall not be permitted.

6.3.3 Galvanic Corrosion—Direct contact of electrolytically dissimilar materials shall be avoided to prevent galvanic corrosion.

6.4 Piping System—The construction of the piping system shall include inlet and outlet Schedule 40 copper-nickel condenser water piping of the proper diameter, extending horizontally outside of the air conditioner cabinet. Construction shall also include the proper size and type of drain piping from the drain connection of the air conditioner through the cabinet down to the deck level.

6.5 Air Conditioner Components:

6.5.1 Compressor—The compressor shall be of the hermetic type for service 1 and service 4 air conditioners and of the open type for service 2 and service 3 air conditioners. Provision shall
be made for adequate lubrication of the rubbing and wearing surfaces, including operation under ship motion, as specified in 7.3. Compressors shall be provided with a crankcase heater. Crankcase heaters shall be replaceable without having to remove oil or refrigerant from the compressor and shall be arranged to provide compressor oil heating before start-up and at any time the compressor is in the off cycle. Compressors shall be provided with suction and discharge compressor service shutoff valves and means for charging.

6.5.1.1 Open Compressor—The open compressor shall be of the positive displacement type. The shaft seal and main bearings shall be replaceable in their entirety without the necessity of replacing or refurbishing the crankshaft or crankcase. Compressor speeds for open compressors shall not exceed 1800 revolutions per minute (t/min).

6.5.1.2 Hermetic Compressor—The hermetic compressor shall be of the positive displacement type.

6.5.2 Condenser—The condenser shall be seawater cooled and constructed in accordance with the criteria shown in Table 1. The condenser shall be sized so that the compressor motor shall not be overloaded when the air conditioner is experiencing overload conditions. The condenser shall be a shell and tube construction with water in the tubes and refrigerant in the shell and shall have an even number of water passes. The condenser shall be mechanically cleanable in place with removable water boxes or heads to permit tubes to be examined, cleaned, or replaced as necessary. The condenser shall be cleanable from either side of the cabinet. Means shall be provided to remove entrained air from each inlet pass. Condenser heat drains shall be provided. Zinc anodes shall be provided in the condenser heads (seawater side). The condenser shall be removable water boxes or heads to permit tubes to be examined, cleaned, or replaced as necessary. The condenser shall be cleanable from either side of the cabinet. Means shall be provided to remove entrained air from each inlet pass. Condenser heat drains shall be provided. Zinc anodes shall be installed in the condenser heads (seawater side). The condenser shall have a means for purging air and noncondensable gases and a relief valve to prevent overpressurization of the refrigerant side. The tube sheets shall be of copper-nickel (90-10) UNS C70600. The condenser heads shall be of valve bronze, Specification B 61, or nickel-aluminum-bronze, Specification UNS C70600. The tubes shall be 19-mm outside diameter, constructed of copper-nickel (90-10) UNS C70600. The tubes shall be extruded fin type. Drain and vent fittings and zinc anode holders shall be nickel-copper (70-30) UNS C71500.

6.5.3 Liquid Receiver—The liquid receiver shall have an internal volume at least 25 % greater than the volume of the complete refrigerant charge. The receiver shall contain an outlet shutoff valve and pressure relief device.

6.5.4 Cooling Coil—The cooling coil (evaporator) shall be of finned-tube construction and shall be composed of copper tubes, in accordance with Specification B 75, or aluminum tubes with copper fins. Fins shall be firmly bonded to the tube. A drip pan and drain for collecting the condensate shall be furnished.

6.5.5 Water-Regulating Valves—A water-regulating valve shall be provided at the outlet to each condenser. The valve shall be direct-acting or pilot-controlled actuated by condenser gas pressure to modulate the flow of water required for the condenser. The valve shall withstand seawater inlet pressures up to 1.37 MPa. The valve shall be constructed of nonferrous or corrosion-resisting material. The valve shall be constructed to prevent the entry of seawater into the refrigerant system in the event of derangement.

6.5.6 Strainer—A strainer shall protect the condenser and water-regulating valve. The strainer shall be not less than 19 mm n.p.s. However, it shall be sized as to not restrict seawater flow during overload conditions. The strainer shall be shipped loose for installation in the seawater piping during air conditioner installation.

6.5.7 Expansion Valve—Refrigerant flow to the cooling coil (evaporator) shall be controlled by a thermostatic valve. The valve shall be an adjustable superheat, externally equalized type. The valve body shall be of cast or forged brass or bronze, and the inlet and outlet connections shall be an integral part of the valve body.

6.5.8 Piping—Any piping necessary for the operation of the equipment shall be provided up to and including fittings at each unit required for interconnection to supplementary service. Exterior connection fittings shall be capped or plugged to safeguard against damage before installation. The water regulating valve shall be installed in the condenser water discharge line and shall be readily accessible for adjustment and maintenance. Condenser water supply piping and drain piping shall be copper-nickel alloy 706. Water pipe fittings and seawater connections shall be 90-10 copper-nickel, valve bronze in accordance with Specification B 61 or monel. No tapered pipe threads shall be used anywhere in the unit. Refrigerant piping shall have readily accessible test fittings for high and low pressure and for charging and draining refrigerant. Refrigerant pipe fittings shall be in accordance with Specification B 16/B 16M. Refrigerant piping and evaporator condensate drain tube shall be copper in accordance with Specification B 75, alloy 12200.

6.5.8.1 Disposable Dehydrator—A disposable dehydrator shall be provided in the refrigerant circuit. The dehydrator shall be equipped with an auxiliary screen or other protective means at the dehydrator outlet to prevent passage of the dehydrating
shall be replaceable, without removal of the blower, from the accordance with Federal Specification FF-B-171. Bearings shall be replaceable permanently lubricated ball bearing type in supported by not less than two self-aligning bearings. Bearings quiet in operation. They shall be secured to shafts and shall be mission of noise generated by the air conditioner to surround-
cabinet.

protection of the plenum shall be identical to that for the air flow in both horizontal and vertical planes. Corrosion air flow. The outlet louvers shall permit adjustable directional structuring to mount on top of the cabinet. The plenum shall outlets shall be interconnected to a common drain tube.

condensate under conditions as specified in 7.4. The drip pan have depth and baffles and multiple drain outlets to prevent condensate from the cooling coil (evaporator). The pan shall be constructed for front air intake and top air discharge. The air intake shall be provided with a protective grill. The front of the machinery compartment shall be provided with a removable panel for servicing the equipment. The back of the machinery compartment shall be enclosed with an expanded metal screen for service 2 and service 3 air conditioners. After fabrication, the cabinet shall be galvanized or coated with one coat of metal primer and enamel topcoat to protect from corrosion. Brackets or integral frame members shall be provided for mounting and fastening the air conditioner to a deck foundation.

Cabinet—The cabinet enclosure shall be constructed of steel or aluminum protected against corrosion. Aluminum shall be Specification B 209, alloy 5052, temper H-32¼ hard. Steel shall be low carbon steel, Specification A 569/A 569Mor equivalent. The cabinet shall incorporate framing, chassis, and support for any component of the air conditioner. The cabinet, framing, and chassis shall support and maintain proper alignment and arrangement of every component under the ship operational conditions as specified in 7.4. The air handling section of the cabinet shall be constructed for front air intake and top air discharge. The air intake shall be provided with a protective grill. The front of the machinery compartment shall be provided with a removable panel for servicing the equipment. The back of the machinery compartment shall be enclosed with an expanded metal screen for service 2 and service 3 air conditioners. After fabrication, the cabinet shall be galvanized or coated with one coat of metal primer and enamel topcoat to protect from corrosion. Brackets or integral frame members shall be provided for mounting and fastening the air conditioner to a deck foundation.

Drip Pan—A condensate drip pan shall collect condensate from the cooling coil (evaporator). The pan shall be constructed from corrosion-resistant material. The pan shall have depth and baffles and multiple drain outlets to prevent overflow of the condensate and provide for draining of the condensate under conditions as specified in 7.4. The drip pan outlets shall be interconnected to a common drain tube.

Plenum—An air discharge plenum shall be provided when specified. The plenum shall be detachable and constructed to mount on top of the cabinet. The plenum shall contain air guide vanes and louvers as required for directing the air flow. The outlet louvers shall permit adjustable directional air flow in both horizontal and vertical planes. Corrosion protection of the plenum shall be identical to that for the cabinet.

Insulation—Thermal insulation shall be applied as necessary to the cabinet, piping, and components to prevent sweating, dripping, running off, or blowing off of moisture. Acoustical insulation shall be applied to minimize the transmission of noise generated by the air conditioner to surrounding areas.

Fans—Fans shall be of the centrifugal type and be quiet in operation. They shall be secured to shafts and shall be supported by not less than two self-aligning bearings. Bearings shall be replaceable permanently lubricated ball bearing type in accordance with Federal Specification FF-B-171. Bearings shall be replaceable, without removal of the blower, from the front or sides of the unit after removal of the service panel.

6.5.13 Air Filter—Air filters shall be arranged to filter ventilation or recirculated air before it enters the evaporator. Filters shall be of the permanent washable type. Materials used in the construction of the filters shall be corrosion-resisting or aluminum. The air filters shall be arranged so they shall not come in contact with condensate from the cooling coils.

6.5.14 Electrical Equipment—The electrical equipment shall be in accordance with NEMA MG 1 and NEMA ICS 1 and shall operate in a 50°C ambient temperature. No portion of the electrical circuit shall be grounded. The frames or enclosures of all electrical components shall be grounded to the frame of the air conditioning unit to eliminate hazard from shorts or grounds within the equipment. The air conditioner shall be provided with a motor controller for remote mounting. Electrical equipment for Type II air conditioners shall meet the requirements of Code of Federal Regulations, Title 46, Subchapter J, Subpart 111.105.

6.5.14.1 Motors—Motors shall be constant speed, continuous duty, with a maximum speed of 3600 r/min, and shall be for the power supply specified. The temperature rise of motors in accordance with NEMA MG 1 shall not exceed 21°C and they shall be provided with built-in thermal protectors installed in accordance with NEMA MG 1. The motors shall be drip-proof or explosion-proof enclosed. Motors shall start the compressor with the maximum refrigerant pressure differential.

6.5.14.2 Motor Controls—Enclosure of the compressor and fan motor controllers shall be one of the following types, as specified,

(1) Drip-proof (45°), watertight, submersible (4.5 m).
(2) Explosion-proof.
(3) Splash-proof.

For hermetic units, overload relays shall be in addition to, and coordinated with, thermal protectors built into the motor. Fans shall be protected with an overload relay or built-in thermal protector. The compressor shall not start or run unless the fan is operating and the compressor shall stop if the fan motor circuit is interrupted. A time delay circuit shall be provided to prevent restarting of the compressor manually or automatically within 5 min of having been stopped for any reason. Delay shall not preclude initial starting of the air conditioner.

6.5.14.3 Controls—A selector switch shall permit operation of the fan only, or of the fan and refrigerating equipment. High pressure and low pressure safety switches and a temperature control shall be provided. The selector switch shall be of a three-position type with an off position to secure both the fan and refrigerating equipment. The temperature control shall provide for automatic compressor control. It shall provide for manual adjustment and operate within a temperature range of 18 to 29°C, with a plus or minus 3°C tolerance. The selector switch shall be readily accessible. The temperature control shall be located within the machinery compartment. The unit shall have separate pressure switches properly set to stop the compressor when the refrigerant discharge pressure rises too high, or suction pressure becomes too low. The pressure controls shall be individual units of the lock open, manual reset type. Pressure and temperature controls shall be in accordance with UL 873. A terminal block or blocks shall be provided with the remote motor controller enclosure for the interconnection.
of all electrical circuits. The internal wiring within the air conditioner cabinet shall be completed to an enclosure containing the necessary terminal blocks, within the cabinet, for interconnection to the motor controller enclosure. Control switches or other electrical devices located external to the motor controller enclosure shall not have protruding or unprotected electrical connection lugs or terminals. Control switches requiring mechanical adjustment shall not be located within the motor controller enclosure unless provision is made so that the necessary adjustments can be made without removing the enclosure cover. When these control switches are located within the air conditioner cabinet, they shall be mounted directly or indirectly, by means of mounting brackets or mounting plates, to the cabinet structure to minimize the effect of vibration from the rotating machinery. They shall be located to minimize the possibility of personnel coming in contact with live electrical parts when servicing the controls.

7. Performance Requirements

7.1 Operation—Operation shall automatically maintain the environmental conditions for which the equipment is set as specified in Table 1.

7.2 Air-Circulating Equipment—The unit shall have the capacity for circulating air through the air conditioning unit at not less than 0.7 m³/min per 290 W of cooling capacity.

7.3 Ship Inclination—The air conditioner shall operate on a surface ship while withstanding 15° permanent, or 45° cyclic, inclination.

7.4 Capacity—Air conditioner shall deliver not less than its specified capacity when operating at the rating conditions as shown in Table 1. The net capacity shall be exclusive of all electrical energy (heat energy) required to operate the compressor, fan, and other units. The air flow quantity shall be at least that specified in Table 1.

7.5 Overload—The temperature rise for motors shall not exceed 70°C for motors in accordance with NEMA MG 1.

7.6 Condensation—The air conditioner shall operate without dripping, running, or blow off of moisture either inside or outside the cabinet.

8. Other Requirements

8.1 Manuals—Manuals shall be prepared in accordance with the manufacturer’s commercial practice. Photo views of the equipment shall be included as part of the general description. A section shall be included containing reduced copies of all drawings required to amplify or illustrate the text, including diagram and assembly drawings. The manual shall contain a parts list and all data necessary to install, operate, repair, and maintain the equipment.

9. Dimensions

9.1 Maximum dimensions of the air conditioner cabinets, including mounting brackets and plenums, shall be as shown in Table 2.

10. Sampling

10.1 When first article inspection is specified, the first air conditioner of each type, service, and size produced under the contract or order shall be selected for testing.

### TABLE 2 Cabinets and Plenum Dimensions

<table>
<thead>
<tr>
<th>Size</th>
<th>Height, m</th>
<th>Width, m</th>
<th>Depth, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.65</td>
<td>0.91</td>
<td>0.56</td>
</tr>
<tr>
<td>3</td>
<td>1.65</td>
<td>1.02</td>
<td>0.61</td>
</tr>
<tr>
<td>5</td>
<td>1.65</td>
<td>1.14</td>
<td>0.64</td>
</tr>
<tr>
<td>7½</td>
<td>1.65</td>
<td>1.22</td>
<td>0.64</td>
</tr>
</tbody>
</table>


11.1 Responsibility for Inspection—Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified in this specification. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified in this specification. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

11.2 Responsibility for Compliance—All items shall meet all specification requirements. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of assuring that all products or supplies submitted comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however this does not authorize submission of known defective material, either indicated or actual.

12. Test Methods

12.1 Classification of Inspections—The inspection requirements specified in this specification are classified as follows:

1. First article inspection (see 12.2)
2. Quality conformance inspection (see 12.3)

12.2 First Article Inspection—When specified in the contract or purchase order, first article inspection shall consist of the tests and examinations as specified in 12.4 and 12.5-12.5.4.3.

12.3 Quality Conformance Inspection—Quality conformance inspection of each air conditioner shall consist of the tests and examinations as specified in 12.4 and 12.6-12.6.2.

12.4 Visual Examination—Each sample unit shall be examined for adjustments, fits, leaks, material, finish, and general conformance to this specification as follows:

1. The external fittings shall be properly secured.
2. Bolts, nuts, and screws shall be tight; equipment and parts shall be properly fastened and secured.
3. No parts shall be fractured, split, torn, dented, or otherwise damaged such as to affect serviceability.
4. There shall be no sharp or ragged edges on the sheeting that may be injurious to personnel.
5. Cold lines shall be properly insulated.
(6) The limiting and mounting dimensions shall be in accordance with drawings and Table 2.

(7) The temperature control shall be properly set and functioning.

(8) The selector switch shall operate satisfactorily.

(9) There shall not be any dripping, running, or blowing off of moisture.

(10) The low pressure and high pressure switch shall be functioning and properly set in accordance with the manufacturer’s specification.

(11) There shall be no refrigerant leakage at any brazed, welded, or mechanical joint as measured using an electronic halide leak detector adjusted to detect a leak of 14 g per year.

12.5 First Article Test Procedures:

12.5.1 General—Before testing, the air conditioner shall have successfully passed the visual examination specified in 12.4. For first article tests, fresh water may be used in lieu of seawater for cooling.

12.5.2 Inclination—The unit shall be inclined at an angle of 15° each side of the vertical in each of two vertical planes at right angles to each other and operated at least 1 h or cycled at 45° for 1 h, under applied rating conditions as specified in Table 1. Test information shall be monitored at 10-min intervals throughout the test. The unit shall be acceptable if there is no spillage of fluids inside or outside the cabinet, no abnormal noise, and no loss of capacity.

12.5.3 Capacity Rating—Capacity rating tests shall be conducted in accordance with the procedures and requirements indicated in ASHRAE 37 and ARI 210. A standard rating test shall be conducted using standard rating conditions in accordance with ARI 210. An application rating test shall be conducted using the operating conditions as shown in Table 1.

12.5.4 Performance—The unit to be tested shall be given the continuous operating tests as specified in 12.5.4.1-12.5.4.3 under the average temperature conditions as indicated with a tolerance of ±0.5°C dry bulb, ± wet bulb, and ± condenser water temperature. Observations and readings shall be taken at intervals not greater than 10 min.

12.5.4.1 Overload—The unit shall be operated with 38°C dry bulb temperature, 30°C wet bulb temperature unit-ambient-air and room air entering-air-inlet, and 38°C water to the condenser. The test shall be continued until steady conditions have been observed for not less than 4 h. The unit shall operate normally without any interruption caused by tripping of motor-overload devices, without damage to motors as a result of overheating, and without injury to any other component part from any operational cause. The temperature rise of the compressor motor winding shall be determined at the end of this test. The temperature rise shall not be greater than that as specified in 6.5.14.1. The temperature rise of the windings shall be measured and computed by the resistance method. In addition, the air conditioner shall be tested to determine actual capacity under overload conditions as shown in Table 1.

12.5.4.2 Condensation—The unit shall be operated continuously for 4 h with 35°C condenser inlet water, 27°C dry bulb temperature, and 24°C wet bulb temperature unit-ambient-air and room air entering-air-inlet. The air conditioning unit shall perform satisfactorily during the test without dripping, running, or blowing off of moisture either inside or outside the cabinet.

12.5.4.3 Air Delivery—The unit shall be provided with a means of restricting the outlet air to produce the minimum outlet resistance as specified in Table 1. The air flow quantity shall be not less than that specified in Table 1.

12.6 Operating Tests—Each air conditioner shall be operated for a period of at least 1 h with controls set to allow continuous compressor operation as shown in Table 1. During this test, inlet air temperature to the evaporator shall be not less than 24°C dry bulb. At the conclusion of this operation test, the entire refrigerant circuit connections under refrigerant pressure shall be tested to determine leakage. In the event of leakage, the leaks shall be repaired and the operating test shall be repeated.

12.6.1 Controls—During this test it shall be verified that the controls are adjusted and functioning properly.

12.6.2 Electrical Power—The electrical power input shall be recorded during operating tests and compared with the input of all other units which have been tested. If any unit requires 7% more power than the average of all the acceptable units, it shall be rejected.

13. Rejection and Rehearing

13.1 Test Failure—Failure of the first article air conditioner to pass any of the tests or examinations specified in this specification shall constitute rejection of the air conditioner design. The resumption of tests and examinations will be considered by the contracting activity after receipt of information substantiating that the deficiencies found have been corrected satisfactorily.

13.2 Acceptance Criteria—Production units failing to meet the tests specified in 12.6-12.6.2 shall be repaired, defective parts and components replaced, and retested until specification requirements are met before offering the air conditioner for acceptance.

14. Certification

14.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

15. Product Marking

15.1 Identification plates shall be made of brass, aluminum, or corrosion-resisting steel. Information plates shall be made of laminated plastic, aluminum, or corrosion-resisting steel. The identification plate shall be located in the front of the machinery compartment. Identification plates shall be secured to equipment with electrolytically compatible fasteners and shall contain the following information:

(1) Name of equipment: Air conditioner,
(2) Manufacturer’s name and address,
(3) Manufacturer’s model, type, capacity,
(4) Manufacturer’s serial number,
(5) Date of manufacture,
(6) Contract or purchase order number, and
(7) Specification number and appropriate type, service, class, size (cooling capacity), and power supply.

15.2 A warning plate shall be mounted on the motor controller enclosure with the following engraving in red letters:

“WARNING: DANGER HIGH VOLTAGE”

15.3 In addition to the identification plate, equipment for explosion-proof applications shall have a warning plate. The warning plate shall be located on the front of the cabinet. Lettering shall be readily legible, reading as follows: “Caution: This Equipment is for Explosion-Proof Application. Disconnect Power Supply Before Opening Electrical Box Covers. Do Not Energize Unless the Equipment is Fully Assembled and All Electrical Enclosures are Properly Closed.”

16. Packaging and Package Marking

16.1 Packaging and package marking shall be in accordance with Practice D 3951.

16.2 For government packaging and package marking, see Supplementary Requirements.

17. Keywords

17.1 air conditioner; air discharge plenum; compressor; condensing unit; evaporator; liquid receiver; mechanically refrigerated

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are applicable to Department of Defense procurements and shall apply only when specified in the contract or order.

S1. Referenced Documents

S1.1 ASTM Standards:² D 3951 Standard Practice for Commercial Packaging

S1.2 Federal Specifications:⁹ TT-P-664 Primer Coating, Alkyd, Corrosion-Inhibiting, Lead and Chromate Free, VOC Compliant

PPP-F-320 Fiberboard: Corrugated and Solid Sheet Stock (Container Grade) and Cut Shapes

S1.3 Military Specifications:⁹ MIL-P-116 Preservation, Methods of

MIL-L-19140 Lumber and Plywood, Fire- Retardant Treated

S1.4 Military Standards:⁹ MIL-STD-1186 Cushioning, Anchoring, Bracing, Blocking and Waterproofing; With Appropriate Test Methods

MIL-STD-2073-1 DoD Material Procedures for Development and Applications of Packaging Requirements

S2. Ordering Information

S2.1 Orders for equipment using this supplement shall include the following information in addition to the ordering information from the basic specification:

S2.1.1 Fire retardant material requirements (see S3.1.1).

S2.1.2 Preservation requirements (see S3.2).

S2.1.3 Packing requirements (see S3.3).

S2.1.4 Required waterproofing (see S3.3.5).

S2.1.5 Package marking requirements (see S3.4).

S3. Packaging

S3.1 Fire Retardant Requirements:

S3.1.1 Treated Lumber and Plywood—Unless otherwise specified, all lumber and plywood including laminated veneer material used in shipping containers and pallet construction, members, blocking, bracing, and reinforcing shall be fire retardant treated material conforming to MIL-L-19140 as follows:

<table>
<thead>
<tr>
<th>Levels A and B</th>
<th>Type II—weather resistant</th>
</tr>
</thead>
</table>
| Category 1—general use

S3.1.2 Fiberboard—Fiberboard used in the construction of class domestic, nonweather-resistant fiberboard, cleated fiberboard boxes, including interior packaging forms, shall meet the flame spread index and the specific optic density requirements of PPP-F-320 and amendments thereto.

S3.1.3 Cushioning and Wrapping Materials—The use of excelsior, newspaper, shredded paper (all types), and similar hygroscopic or nonneutral materials and all types of loose fill materials for packaging applications, such as cushioning, fill, stuffing, and dunnage is prohibited. Materials selected for cushioning and wrapping shall have properties (characteristics) for resistance to fire. Cushioning or wrapping materials, as applicable, shall be provided to prevent item and package damage and to prevent free movement of the container contents.

S3.2 Preservation—Preservation shall be level A or commercial as specified.

S3.2.1 Level A—Each complete unit shall be unit protected in accordance with Method I requirements of MIL-P-116 and as follows: exterior unpainted ferrous metal surfaces shall be coated with P-19 preservative in accordance with MIL-P-116. The water cooling system shall be thoroughly drained and blown out by the application of clean, dry compressed air. To prevent the entrance of foreign material, all openings shall be sealed with the use of metal or plastic plugs or waterproof pressure-sensitive tape. Drive belts shall be removed, exposed uncoated ferrous metal surfaces of pulleys and shafts shall be cleaned and coated with primer in accordance with TT-P-664. When the primer is thoroughly dry, drive belts shall be remounted in place with tension on the belts relaxed.

S3.2.2 Commercial—Commercial preservation shall be in accordance with Practice D 3951.

S3.3 Packing—Packing shall be Level A, B, C, or commercial as specified.
S3.3.1 General—Shipping containers shall contain identical quantities of identical material and shall be of minimum weight and cube, similar construction, and of uniform size.

S3.3.2 Level A, B, and C Containers—Material preserved as specified shall be packed in shipping containers, cleated plywood, or nailed and locked corner boxes or covered crates, for the level of packing specified, in accordance with MIL-STD-2073-1, Appendix C, Table 7. Unless otherwise specified, container selection shall be at the contractor’s option.

S3.3.3 Closure—Container closure, reinforcing, or banding shall be in accordance with the applicable container specification or appendix thereto except that class weather resistant fiberboard boxes shall be closed in accordance with MIL-STD-2073-1, Method V, and reinforced with nonmetallic or tape banding, and nonweather resistant fiberboard boxes shall be closed in accordance with Method I using pressure-sensitive tape.

S3.3.4 Weight—Wood, plywood, and cleated-type containers exceeding 90-kg gross weight shall be modified by the addition of skids in accordance with MIL-STD-2073-1 and the applicable container specification or appendix thereto.

S3.3.5 Waterproofing—Unless otherwise specified, level A and when specified, level B, shipping containers shall be provided with caseliners, linings, wraps, or shrouds in accordance with the waterproofing requirements of MIL-STD-1100.

S3.3.6 Commercial—Material preserved as specified shall be packed for shipment in accordance with Practice D 3951. Shipping containers exceeding 90-kg gross weight shall be provided with the minimum of 0.08 by 0.1-m nominal wood skids laid flat, or a skid- or sill-type base that will support the material and facilitate handling by mechanical handling equipment during shipment.

S3.4 Marking

S3.4.1 Level A, B, and C and Commercial Marking—In addition to any special marking required, level A, B, and C interior packs and shipping containers shall be marked in accordance with MIL-STD-2073-1, Appendix F, and commercial interior packs and shipping containers shall be marked in accordance with Practice D 3951. In addition, bar coding shall be applied in accordance with the marking requirements of MIL-STD-2073-1 and the shipment marking information shall be provided on interior packages and exterior shipping containers and shall include the following:

1. Nomenclature,
2. National stock number,
3. Manufacturer’s part number,
4. Size,
5. Contract or order number,
6. Contractor’s name, and
7. Destination.

S3.5 Technical Manuals—Technical manuals that accompany shipment shall be packaged in a transparent waterproof plastic bag, minimum 4 mil thick. Closure shall be by heat sealing. The copy(s) of the manual shall be placed in the shipping container housing the main unit. Packing lists shall indicate which container contains the technical manual(s) and shall state the approximate location therein. The manual shall be readily accessible when the container is opened. Technical manuals, when shipped in bulk quantities, shall not be individually wrapped, but shall be packed in accordance with the requirements of the applicable technical manual specifications.

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Standard Practice for Inclined Cargo Tank Ladders

This standard is issued under the fixed designation F 1437; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides design, construction, and installation criteria for inclined ladders to be installed within cargo tanks.

1.2 Where ladders are attached to platforms, see Fig. 1 and Fig. 2.

1.3 Values stated in SI units are to be regarded as the standard. The values stated in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A 36M Specification for Structural Steel

2.2 Other Documents:
American Bureau of Shipping Rules for Building and Classing Steel Vessels
American Welding Society Publication, AWS D 1.1 Structural Welding Code—Steel
SAE AMS-C-27725 Coatings, Corrosion Preventative, Polyurethane, for Aircraft Integral Fuel Tanks for Use to 250 Degrees F (121 Degrees C)
Steel Structures Painting Council Specification

3. Classification

3.1 Ladders shall be classified into two types:

3.1.1 Type I—Ladders installed within cargo tanks carrying cargo other than fuel oil, and

3.1.2 Type II—Ladders installed within cargo tanks carrying fuel oil.

4. Significance and Use

4.1 This practice establishes the procedure for the construction and installation of inclined ladders to be fabricated and installed, by the shipyards, within the cargo tanks.

5. Materials and Manufacture

5.1 Materials—(Type I):
5.1.1 Stringers—230-mm (approximately 9-in.) by 50-mm (approximately 1 ¾-in.) structural channels of carbon steel. (See Specification A 36/A 36M.)

5.1.2 Upper and Lower Clips—Flat bars of carbon steel. (See Specification A 36/A 36M.)

5.1.3 Handrails and Stanchions—25 mm (approximately 1 in.) diameter carbon steel. (See Specification A 36/A 36M.)

5.1.4 Treads—75-mm (approximately 3-in.) by 10-mm (approximately ¾-in.) structural angles of carbon steel. (See Specification A 36/A 36M.)

5.2 Materials—(Type II):
5.2.1 Stringers—Structural flat bars of carbon steel. (See Specification A 36/A 36M.)

5.2.2 Upper and Lower Clips—Flat bars of carbon steel. (See Specification A 36/A 36M.)

5.2.3 Treads—25-mm (approximately 1-in.) by 25-mm square bars of carbon steel. (See Specification A 36/A 36M.)

5.3 Manufacture:
5.3.1 All welding shall be in accordance with American Bureau Shipping Rules for Building and Classing Steel Vessels or AWS D 1.1.

6. Dimensions

6.1 Dimensions indicated are typical. However, these dimensions can be changed to suit other existing structures.

6.2 The tread lengths, or the clear widths, between the stringers for Type I ladders, for commercial and naval ships, shall be 455 mm (approximately 18 in.) and 610 mm (approximately 24 in.), respectively.

6.3 The tread lengths or clear widths between stringers for Type II ladders shall be 380 mm (approximately 15 in.).

6.4 The lengths of the ladder shall be fabricated to suit existing requirements.

6.5 Tolerance shall be ±6 mm (approximately ¼ in.).
6.6 Type I ladders shall have the following dimensions: installed angle: 50 to 69° from the horizontal; tread depth: 175 to 250 mm (approximately 7 to 10 in.) at 50°, tapering to 75 mm (approximately 3 in.) at 69°; riser height 175 to 300 mm (approximately 7 to 12 in.); handrail 25 to 31 mm (1 to 1 1/4 in.) in diameter.

6.7 Type I ladder tread surfaces shall have slip-resistant surfaces of a material compatible with materials to be carried in that tank.

6.8 Type II ladders shall be as follows: installed angle 70 to 90° from the horizontal; treads shall be equally spaced at a maximum of 305 mm (approximately 12 in.); the distance from the top tread to the upper walking surface is to be approximately equal to the normal tread spacing; and the distance from the bottom tread to the lower walking surface is not to exceed 375 mm (approximately 15 in.).

7. Workmanship, Finish, and Appearance

7.1 Ladders shall be free of all sharp edges, burrs, projections, weld splatter, and other defects which might be injurious to personnel or equipment or both.

7.2 For cargo tanks carrying cargo other than fuel oils, coat the ladders with one coat 3.0-mil dry film thickness inorganic zinc silicate following surface preparation in accordance with the Steel Structures Painting Council specifications or manufacturers paint instructions.
7.3 For spaces carrying fuel oil cargo, one coat of 3.0-mil dry film thickness of corrosion preventive coating shall be applied to the ladders in accordance with SAE-AMS-C-27725.

7.4 Connections between ladders and mounting clips may be bolted in lieu of the welding shown.

8. Keywords

8.1 cargo tank access; cargo tank ladders; inclined ladders; ladders
Standard Guide for
Selection of Structural Details for Ship Construction

This standard is issued under the fixed designation F 1455; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The principal aim of this guide is to depict recommended practices related to the design of ship structural details. The importance of structural details is clear:

1) Their layout and fabrication represent a sizable fraction of hull construction costs.

2) Details are often the source of cracks and other failures which, under certain circumstances, could lead to serious damage to the ship hull girder.

3) The trend toward decreasing ship hull scantlings (that is, increasing average hull stresses) has the potential of increasing the damage to details.

4) Researchers have largely neglected the analysis of structural details at least in part because the configuration and purpose of these details vary greatly and are not commonly described or discussed in the literature.

Due to lack of analytical and experimental effort devoted to structural details, their determination has been left up to draftsmen and designers, with very little engineering input.

In two comprehensive reviews\(^2\,^3\) of the performance of structural details, 86 ships were surveyed. These included naval and commercial ship types. The commercial ships included both U.S. and foreign built. The vessels ranged from 428 to 847 feet in length, from 18,000 to 90,000 tons in displacement, and from five to twenty-six years in age. The details obtained were grouped into 12 typical families. Knife Edge Crossings (Family No. 6) and Structural Deck Cutout Details (Family No. 9) are shown but not covered in detail in this guide. The remaining ten detail families were further categorized into 53 groups comprising a total of 611 detail configurations. A number of these configurations are very similar to others in detail geometry and such duplicates have been excluded from this guide. A number of others were eliminated because of relatively infrequent observed use. As a result, a total of 414 details are included herein. However, all 611 details can be found in “Structural Details,”\(^4\) if desired.

In total, 607,584 details were observed with a total of 6,856 failures. Failures were attributed to one or a combination of five categories: design, fabrication, welding, maintenance, and operation (see 4.1 through 4.5). This extensive, well documented research, together with engineering judgement, provides the principal support for this guide.

1. Scope

1.1 This guide provides a recommended list of selected ship structure details for use in ship construction.

1.2 Structural details which have failed in service and are not recommended for use in ship construction are included as well.

1.3 This guide is intended to convey the lessons learned on different configurations of ship structure details, not the dimensions, thickness, or construction methods which would result from structural calculations.\(^4\)

2. Terminology

2.1 Definitions of Terms Specific to This Standard:

2.1.1 Terms:

2.1.2 beam bracket—a bracket at the end of framing or stiffening members that is used for increased strength, continuity and end constraint.

\(^1\) This practice is under the jurisdiction of ASTM Committee F25 on Shipbuilding and is the direct responsibility of Subcommittee F25.01 on Structures.


2.1.2.1 Discussion—see Fig. 1.

2.1.3 clearance cut-outs—a hole or opening in a pierced member to allow passage of a piercing member.

2.1.3.1 Discussion—see Fig. 2.

2.1.4 gunwale connection—the connection of the sheer strake to the stringer strake of the uppermost deck of the hull.

2.1.4.1 Discussion—see Fig. 3.

2.1.5 knife edge crossing—the projected point intersection of members (plate members, stiffeners or bulkheads) on opposite sides of an intervening plate member. An undesirable condition to be avoided.

2.1.5.1 Discussion—Included for information only, see 3.1.

2.1.5.2 Discussion—see Fig. 4.

2.1.6 miscellaneous cut-out—small holes or openings of a variety of sizes and shapes used for access, drainage, ease of fabrication, stress relief, and so forth.

2.1.6.1 Discussion—see Fig. 5.

2.1.7 non-tight collar—a fitting at the cut-outs in way of the intersection of two continuous members that provides lateral support for the piercing member which does not fully fill the cut-out area of the pierced member. May be a lug.

2.1.7.1 Discussion—see Fig. 6.

2.1.8 panel stiffeners—intercostal, non-load-carrying members used to reduce the size of plate panels.

2.1.8.1 Discussion—see Fig. 7.

2.1.9 stanchion ends—structural fittings at the ends (top and bottom) of a stanchion to transfer loads from the supported member to the supporting member.

2.1.9.1 Discussion—see Fig. 8.

2.1.10 stiffener ends—the configuration of the end of an unbracketed, non-continuous stiffener.

2.1.10.1 Discussion—see Fig. 9.

2.1.11 structural deck cuts—allow passage through decks for access, tank cleaning, piping, cable, and so forth.

2.1.11.1 Discussion—Included for information only, see 3.1.

2.1.11.2 Discussion—see Fig. 10.

2.1.12 tight collar—as per non-tight collar but the cut-out in the pierced member is fully filled and is air-, oil-, or watertight as required. Tight collars may be lapped or flush fitted.

2.1.12.1 Discussion—see Fig. 11.

2.1.13 tripping bracket—a bracket or chock that provides lateral support to framing and stiffening members. Support may be provided to either the web or the flange, or to both.

2.1.13.1 Discussion—see Fig. 12.

2.2 Symbols:

2.2.1 Symbols are as indicated in Fig. 13. The detail identification symbol (Fig. 13, 1-J-1 for example) is the same as that assigned in the original research reports and is retained throughout for all details for ease in referring back to the reports if desired.

3. Summary of Guide

3.1 In this guide, details are shown for the ten families of structural details identified above and as shown in Fig. 1–3, 5–9, 11 and 12. Knife Edge Crossings, Fig. 4, are not discussed further in this guide since none were observed in the research and fortunately so. This detail represents very undesirable structural conditions and is to be avoided. Structural Deck Cuts, Fig. 10, are not discussed in this guide since this detail
must be considered in relation to the size of the opening and its proximity to primary structures.

3.2 Evaluation of details shown in Figs. 14-28 is based on in-service experience as described in “Design Guide for Structural Details”. Data for over 400 details is summarized and rated in the figures by observed relative successful performance. Each of the ten families of details include configurations with no signs of failures. The details without failures within each family group are shown in descending order of numbers observed. Those details with failures are shown in ascending order of failures (percentage are indicated for each). Thus the first detail shown in each family group has the best observed service performance and is most highly recommended while the last has the highest failure rate and therefore least desirable.

3.3 These details, rated as indicated above, provide guidance in the selection of structural detail configurations in future design and repair of such details.

4. Failure Causes

4.1 Failures in the details shown in Figs. 14-28 were attributed to either one or a combination of five categories: design, fabrication, welding, maintenance, and operation.

4.1.1 Design

4.1.1.1 Design failures generally resulted from the omission of engineering principles and resulted in a buckled plate or flange; the formation of a crack in a plate, flange or web; or the rupture of the bulkhead, deck or shell. Each of the families, with the exception of tight collars, had detail failures attributed to design.

4.1.1.2 Failures directly related to design in structural details and supporting members were the result of being sized without adequate consideration of applied forces and resulting deflections.

4.1.1.3 In the beam bracket configurations of family no. 1 (Fig. 14), 20% of the surveyed failures attributed to design were caused by instability of the plate bracket edge or by instability of the plate bracket panel. This elastic instability, which resulted from loads that produce critical compressive or shear stresses, or both, in unsupported panels of plating, can be eliminated when properly considered in the design process.

4.1.1.4 The failures of beam brackets by cracking occurred predominately where face plates had been sniped, at the welded connections, at the ends of the brackets, at cutouts in the brackets, and where the brackets were not properly backed up at hatch ends. The sniping of face plates on brackets prevents good transition of stress flow, creates hard spots and produces fatigue cracks due to the normally cyclic stresses of these members. Care must be taken to ensure proper transition with the addition of chocks, back-up structure, reinforcement of hole cuts, and the elimination of notches.

4.1.1.5 To reduce the potential for lamellar tearings and fatigue cracks in decks, bulkheads, and beams, transition brackets should be made continuous through the plating or supported by stiffeners rigid enough to transmit the loads.

4.1.1.6 The greater number of failures in the tripping bracket configurations of family no. 2 (Fig. 18), occurred at

hatch side girders, particularly in containerships. This will be a continuing problem unless the brackets are designed to carry the large lateral loads due to rolling when containers are stacked two to four high on the hatches. The brackets must, in turn, be supported by properly designed backing structure to transmit the loads to the basic ship structure.

4.1.1.7 Tripping brackets supported by panels of plating can be potential problems depending on the plate thickness. Brackets landing on thick plating in relationship to its own thickness may either buckle in the panel of the bracket, produce fatigue cracks along the toe of the weld, or cause lamellar tearing in the supporting plate. Brackets landing on plating with a thickness equal to, or less than its own thickness, may cause either fatigue cracks to develop or buckling of an unsupported panel of plating.

4.1.1.8 The non-tight collar configurations of family no. 3 (Fig. 21) experienced only a few failures. There are considerations, however, that must be used by the designer to ensure the continuation of this trend. The cutouts should be provided with smooth well rounded radii to reduce stress risers. Where collars are cut in high stress areas, suitable replacement material should be provided to eliminate the overstressing of the adjacent web plating. These considerations should reduce the incidents of plate buckling, fatigue cracking, and stress corrosion observed in this family.

4.1.1.9 For detail family no. 7, miscellaneous cutouts, (Fig. 24), the reasons for failure were as varied as the types of cutouts. Potential problems can be eliminated by the designer if, during detail design, proper consideration is given to the following:

1) Use generous radii on all cuts.
2) Use cuts of sufficient size to provide proper welding clearances.
3) Avoid locating holes in high tensile stress areas.
4) Avoid square corners and sharp notches.
5) Use adequate spacing between cuts.
6) Properly reinforce cuts in highly stressed areas.
7) Locate cuts on or as near the neutral axis as possible in beam structures.
8) Avoid cuts at the head or heel of a stanchion.
9) Plug or reinforce structural erection cuts when located in highly stressed areas.

4.1.1.10 The most damaging crack observed during the survey was in the upper box girder of a containership. This structure is part of the longitudinal strength structure of the ship in addition to being subjected to high local stresses due to the container loading in the upper deck. Openings in this structure must be located, reinforced, and analyzed for secondary bending stresses caused by high shear loads.

4.1.1.11 The clearance cutouts of family no. 8 (Fig. 20) are basically non-tight collars without the addition of the collar plate. Suggestions made for non-tight collars and miscellaneous cutouts are applicable for this family.

4.1.1.12 Well rounded corners with radii equivalent to 25% of the width perpendicular to the primary stress flows should be used. Special reinforcements in the form of tougher or higher strength steel, inserts, coamings, and combinations of the above should be used where fatigue and high stresses are a problem.

4.1.1.13 In general, failures in stanchion ends, family no. 10 (Fig. 25) were cracks which developed in or at the connection to the attachment structure. The addition of tension brackets, shear chocks, and the elimination of snipes would reduce the incidents of structural failure. All stanchion end connections should be capable of carrying the full load of the stanchion in tension or compression. Stanchions used for container stands or to support such structure as deckhouses on the upper deck should be attached to the deck with long tapered chocks to reduce stress flows from hull induced loads, and in no case should “V” notches be designed into such connections.

4.1.1.14 The stiffener ends in family no. 11 (Fig. 27) with webs or flanges sniped, or a combination of both, or square cut ends sustained failures. In nearly all cases, the failures occurred in the attached bulkhead plating, the web connection when the flange was sniped, or the shear clip used for square cut stiffener ends.

4.1.1.15 Stiffeners that support bulkheads subject to wave slap, such as exposed bulkheads on upper deck, or tank bulkheads, should not be sniped and suitable backing structure should be provided to transmit the end reaction of the stiffeners.

4.1.1.16 While snipping stiffeners ensures easier fabrication, any stiffeners subject to tank pressures or impact type loading
should be restrained at the ends and checked for flange stability to prevent lateral instability under load.

4.1.1.17 Panel stiffeners, family no. 12 (Fig. 28) while classified as not being direct load carrying members, should be designed for the anticipated service load. For instance, panel stiffeners on tank bulkheads, as with any other stiffeners subject to pressure head loads, should be treated the same as other local stiffening.
4.1.1.18 Panel stiffeners used as web stiffeners on deep girders should not be expected to restrain the free flange from buckling in the lateral direction unless they are designed as lateral supports.

4.1.1.19 The design of panel stiffeners should be the same as other local stiffeners with respect to cutouts, notches, and other structural irregularities.

4.1.2 Fabrication:
4.1.2.1 Unexpected stress concentrations produced cracks that initiated from structural cuts, details with poor alignment, and improperly worked materials. Fabrication techniques that ensure proper continuity of structural parts and eliminate
jagged edges and undercut welds would eliminate such failures. The failures caused by fabrication resulted from:

1) Poor cutting techniques (hand cutting or rough cutting with no follow-up dressing).
2) Failure to edge prep cutouts and plate edges after flame cutting.
3) Improper alignment of intercostal structures.
4) High residual stresses due to poor workmanship.

4.1.2.2 The following list should be considered during the fabrication process as an aid to reducing subsequent failures:

1) Consult with the designer before deviating from the design details.
2) Where hard spots, knife edge crossings, or improper tapers occur, consult with the designer to resolve the problem.
3) Avoid misaligned structure.
4) Properly dress the edge of all cuts.
5) Eliminate notches in any structure whether primary or secondary.
6) Only use heat for straightening when approved by design or fabrication documents.
7) Only use cold working in areas approved by design or fabrication documents and then only to the minimum extent possible.
8) Avoid improper edge distances that must be filled with weld.
9) Never leave erection cuts in the structure that are not on the detail plans or approved by the designer.
10) Don't use improper or defective materials.
11) Avoid leaving weld splatters, gouges or other imperfections.

4.1.3 Welding:

4.1.3.1 Cracks in structural welds developed in the heat affected zones, in the weld metal, and in the base metal where irregular weld configurations caused stress concentrations. Proper design and controlled welding procedures would ensure the quality of structural welds and reduce failures associated with welding.

4.1.3.2 Welding was identified as a cause of failure in many cases. Undersized welds, poor deposits or undercutting at the weld toe in areas of poor accessibility were the most common causes of weld failures. Other aspects of welding that are not easily recognized by visual inspection, but influence the formation of weld faults are:

1) Using the wrong type of electrode (this is especially true in ship structures where different material types are mixed).
2) Using the wrong heat input (either too high or too low for the electrode or filler metal being used).
3) Using an improper weld sequence that causes excessive distortion.
4) Using oversized welds by design, or to make up for poor fabrication.
5) Improper weld edge preparation on the plating or stiffener webs.
6) Improper weld cleaning before and between weld passes.
7) Improper back gouging in full penetration welds.

4.1.3.3 The weld and inspection requirements for primary structure is fully covered by the classification societies and the U.S. Navy. However, the requirements for secondary structure such as tripping stiffeners, panel stiffeners, miscellaneous openings and reinforcements are left to the designer’s judgment. Failures in these welds could lead to primary structure failures. Therefore, it is imperative during design and fabrication that requirements for proper welding be given full consideration. Every effort must be made to ensure that sufficient clearances are maintained, that cutouts are sufficiently sized for the welding required, and that all special applications are noted to ensure proper welding controls and weld contours. Access must be provided to allow the welder to reach in corners and behind flanges to ensure good weld contours, and avoid blobs, weld splatters, or weld arc strikes which could become the source of a crack.

4.1.3.4 If a weld is correctly sized, deposited, and inspected, the likelihood of a flaw or crack starting because of the weld is very remote.

4.1.4 Maintenance:

4.1.4.1 Failures were observed on ships that resulted directly from the lack of proper maintenance. Corrosion reduced...
the scantlings of the members below the design allowances with buckles developing from instability and cracks from
excessive stress. Ship owners and operators could eliminate structural failures from such causes if they maintained protective coatings on structures subjected to the corrosive action of the sea.

4.1.4.2 Throughout the design and fabrication process, every effort should be made to eliminate:
1) Areas that allow standing water.
2) Areas that are inaccessible.
3) Areas with ineffective coating materials.
4) Areas with improper location of miscellaneous cutouts.
5) Areas with high residual stresses.

4.1.4.3 Specific failures were attributed to maintenance. The following are suggested corrective measures for combating the cause of such failures:
1) Areas used for water ballast, or subject to casual water and/or salt spray should be coated with anti-corrosive coating.
2) Pockets and low spots should have drain holes, air holes and drain pipes to ensure that water does not stand or pocket on decks, behind structure or tanks. At the same time, the location of these openings should be judiciously considered to eliminate openings in high stress areas where possible and to reinforce those openings when they cannot be located out of those areas. This will reduce the effects of stress corrosion that lead to buckled plates and flanges, and the increase in stress that causes fatigue cracks.
3) Personnel access should be provided to all areas of the ship to afford the opportunity to conduct the necessary inspections and, where required, the preventive maintenance that will reduce costly repairs later.
4) Areas subjected to severe corrosion condition should be designed and fabricated to reduce areas of potential high stress which accelerate corrosion due to stress and fatigue.

4.1.5 Operations:
4.1.5.1 Details in the forward shell and forecastle areas of several ships sustained damage resulting from driving the ship at high speed in heavy weather. With the uncertainty of the slamming loads produced by such conditions, extreme care should be used in the selection, design, fabrication and
maintenance of all structural connections and details used in the forward area of the ship.

4.1.5.2 The majority of these failures were caused by operators trying to maintain a predetermined schedule based on a set course and speed. Other more obvious operations failure causes included cargo handling abuse, docking (drydocking as well as pier side operations), and minor collisions (including other ships, tugs and large floating objects).

4.1.5.3 The most prominent detail failures attributed to operations were to family no. 1 beam brackets, (Fig. 14). Of the beam bracket failures 67% were attributed to operation (heavy weather). Possible fixes for the beam brackets included the use of face plates or panel stiffeners to increase panel stability, the use of heavier plating to increase the corrosion margin and increase panel stability, and the elimination of the indiscriminate use of lighting holes and miscellaneous cutout in areas subject to potentially high operational loading.

4.1.5.4 Tripping brackets, detail family no. 2 (Fig. 18) were the source of numerous operational failures especially in the areas of hatch side girders and bulwark brackets. These girders, which carry high concentrated loads from containers stowed two to four high, must be provided with scantlings and tripping brackets to ensure proper support and load transfer during severe weather.

5. Keywords

5.1 fabrication details; ship construction; structural details
FIG. 21 Performance of Non-Tight Collar Details (Family No. 3)
FIG. 22 Performance of Tight Collar Details (Family No. 4)

FIG. 23 Performance of Gunwale Connection Details (Family No. 5)
FIG. 24 Performance of Miscellaneous Cutout Details (Family No. 7)
FIG. 25 Performance of Stanchion End Details (Family No. 10)
FIG. 26 Performance of Stanchion End Details (Family No. 10) Cont’d
FIG. 27 Performance of Stiffener End Details (Family No. 11)
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FIG. 28 Performance of Panel Stiffener Details (Family No. 12)
Standard Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications

This standard is issued under the fixed designation F 1476; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard provides the performance characteristics and qualification tests required for gasketed mechanical couplings including grooved-type mechanical couplings for grooved end pipe, mechanical restraint couplings for plain end pipe and mechanical compression couplings for plain end pipe. These couplings are for use at temperatures within the recommended temperature range of their respective gaskets. Consult manufacturer for details.

1.2 The values stated in metric units (SI) are to be regarded as the standard. The values given in parentheses (inch/pound) are provided for information purposes.

1.3 Measuring and test equipment (M&TE) used in the performance of the tests described herein shall be calibrated using equipment which is traceable to the National Institute of Standards and Technology (NIST) or calibrated in accordance with the requirements detailed in BS5781 Part 1 against standards traceable to National Standards.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.5 As this is not a dimensional standard, nor does it contain component dimensions, the intermixing of sub-components such as gaskets and housings between manufacturers is not recommended and constitutes non-conformance with this standard.

2. Referenced Documents

2.1 ASTM Standards:
A 47 Specification for Ferritic Malleable Iron Castings
A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 135 Specification for Electric-Resistance-Welded Steel Pipe
A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 183 Specification for Carbon Steel Track Bolts and Nuts
A 193 Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194 Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
A 325 Specification for Structural Bolts, Steel, Heat-Treated, 120/105 ksi Minimum Tensile Strength
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
A 536 Specification for Ductile Iron Castings
A 563 Specification for Carbon and Alloy Steel Nuts
A 574 Specification for Alloy Steel Socket-Hand Cup Screws
B 26/B26M Specification for Aluminum-Alloy Sand Castings
B 88 Specification for Seamless Copper Water Tube
B 580 Specification for Anodic Oxide Coatings on Aluminum
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
D 2000 Classification System for Rubber Products in Automotive Applications
F 837 Specification for Stainless Steel Socket Head Cap Screws
2.2 ANSI, ANSI/ASQC, or ANSI/AWWA Standards:
B 36.10—Welded and Seamless Wrought Steel Pipe
B 36.19—Stainless Steel Pipe
C 151/A21.51—Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids

Footnotes:

2 Annual Book of ASTM Standards, Vol 01.02.
3 Annual Book of ASTM Standards, Vol 01.01.
4 Annual Book of ASTM Standards, Vol 01.06.
6 Annual Book of ASTM Standards, Vol 15.08.
7 Annual Book of ASTM Standards, Vol 02.02.
8 Annual Book of ASTM Standards, Vol 02.01.
9 Annual Book of ASTM Standards, Vol 02.05.
10 Annual Book of ASTM Standards, Vol 09.01.
3. Terminology

3.1 Definitions:
3.1.1 class—differentiates joint characteristics such as rigid, flexible, restrained and unrestrained.
3.1.2 failure—any leakage or joint separation, unless otherwise determined to be due to a pipe or fitting defect.
3.1.3 fitting—a device used to change pipe direction, size or adapt to other joining methods. This device is used with pipe or other fittings to create a working system. Shapes such as elbows, tees, crosses, reducers and special shapes are used as needed to fulfill system design specifications.
3.1.4 flexible—characteristic of a joint wherein there is available limited angular and axial pipe movement.
3.1.5 gasketed mechanical coupling (GMC)—a device used to join pipe to pipe, pipe to fitting, or fitting to fitting wherein an elastomeric (gasket) is used to seal the joint. Coupling may or may not provide mechanical restraint of the pipe or fitting.
3.1.6 grade—the joint working pressure as established by tests using representative pipe or tube and the gasketed mechanical coupling (GMC). Test pipe or tube shall be:
NPS—Standard Weight Steel Pipe per ANSI B 36.10 and Specification A 53 Grade B, or Specification A 135 Grade B.
AWWA—Class 53 Ductile Iron Pipe per ANSI/AWWA C 151/A-21.51 for 3”–16”. For other sizes, consult manufacturer.
Tubing—Type K Copper Tube per Specification B 88.
Other—As agreed to by GMC manufacturer and purchaser.
3.1.7 grooved mechanical coupling (Type I)—a device which consists of two or more housings, closure members such as sets of bolts and nuts or pins, and a pressure-responsive gasket. It is used to mechanically join and seal grooved pipe or fitting, forming a joint. Grooves conform to ANSI/AWWA Standard C 606 as applicable. Groove dimensions for tubing and other sizes and types of pipes shall be as specified by the manufacturer. See Fig. 1.
3.1.8 plain end mechanical coupling:
3.1.8.1 (Type II—Classes 1 and 2)—Device consisting of gasket(s), housing(s), sleeve(s), end rings, threaded fasteners, pipe or fitting anchoring (gripping) features and seal retainers as applicable. These devices are used to create a seal and restrain plain end pipe or fittings. See Fig. 2 and Fig. 3.
3.1.8.2 (Type II—Class 3)—Device consisting of gasket(s), housing(s), sleeve, end rings and threaded fasteners as applicable. Tightening of the fasteners compresses the gasket(s), creating a seal on the outside of the plain end pipe. See Fig. 4.

FIG. 1 Type I Typical Construction

FIG. 2 Type II—Class 1 Typical Construction
3.1.9 joint—interface formed between pipe and pipe, pipe and fitting, or fitting and fitting where a GMC is used to seal within a specified working pressure this interface and where applicable, provide mechanical holding strength.

3.1.10 joint pressure rating—the working pressure for the joint on the pipe or fitting material and thickness to be used in the actual piping application.

3.1.11 leakage—the escape of fluid (gaseous or liquid) from any point of the specimen.

3.1.12 penalty run—a penalty run is performed with penalty run specimens when the original test specimen leaks or separates during testing as a result of any cause which is not related to the design of the GMC being qualified.

3.1.13 penalty run specimen(s)—additional specimen(s) which are tested in the place of the original specimen(s). These additional specimen(s) are assembled using the same methods along with additional GMC’s of the same type, grade, class, and configuration; and additional pipes or fittings with the same sizes, nominal wall thickness material and material condition as the original test specimen.

3.1.14 pipe—hollow tubular products conforming to ANSI B 36.10 and B 36.19, ANSI/AWWA C 151/A-21.51 Nominal Dimensions, or O.D. tube sizes.

3.1.15 pressure responsive gasket—gasket design such that application of a pressure load to the gasket enhances its sealing capabilities; that is, additional pressure results in additional force between the gasket and the surface to which it is sealing.

3.1.16 restrained—characteristic of the joint wherein thrust loads generated by internal pressure or external means are absorbed within the joint.

3.1.17 rigid—characteristic of a joint where there is essentially no available free angular or axial pipe movement.

3.1.18 specimen—a prepared assembly consisting of the test joint including GMC and pipes or fittings. The specimen is placed into a controlled environment and tested to determine if the joint performs to the standards established by the test.

3.1.19 type—differentiation of kind of pipe or fitting which gasketed mechanical couplings (GMC) are used to join (that is, grooved or plain end).

3.1.20 unrestrained—characteristic of a joint wherein thrust generated by internal pressure or external means is not absorbed by the joint but by other means such as pipe anchors or thrust blocks.

4. Classification

4.1 Gasketed mechanical couplings (GMC) are classified into the following design types:

4.1.1 Type I grooved mechanical couplings.

4.1.2 Type II plain end mechanical couplings.

4.2 The gasketed mechanical couplings (GMC) are classified into various grades based on successful completion of testing defined herein. Grades range from approximately 100 psi to 4000 psi and vary by GMC manufacturer. Consult GMC manufacturer for specific grades available.

4.3 The gasketed mechanical couplings (GMC) are classified by the following joint characteristics:

4.3.1 Class 1—rigid and restrained.

4.3.2 Class 2—flexible and restrained.

4.3.3 Class 3—flexible and unrestrained.

5. Ordering Information

5.1 Orders for GMC (Gasketed Mechanical Couplings) under this specification shall include the following:

5.1.1 ASTM designation, title, number and year of issue,

5.1.2 Quantity (number of gasketed mechanical couplings),

5.1.3 Size and appropriate suffix (examples: 8” NPS, 76.1 mm OD),

5.1.4 Type (I, II),

5.1.5 Grade (consult GMC manufacturer),

5.1.6 Class (joint characteristic),

5.1.7 Housing material and finish,

5.1.8 Gasket material,

5.1.9 Bolt (stud) and nut material and finish,

5.1.10 Supplementary requirements, if any,

5.1.11 Other requirements agreed to between purchaser and GMC manufacturer.

5.2 Optional Ordering Requirements:

5.2.1 Certification requirements,

5.2.2 Special marking requirements.

6. Materials and Manufacture

6.1 Type I—Grooved Mechanical Coupling:

6.1.1 Grooved Mechanical Coupling Housings:

6.1.1.1 Ferrous Materials—Housings shall be constructed of ductile iron in accordance with Specification A 395 Grade 60–40–18 or 65–45–15, Specification A 536, Grade 65-45-12 or malleable iron in accordance with Specification A 47, Grade 32510 or 35018.

6.1.1.2 Grooved mechanical coupling housings shall be coated with the manufacturer’s standard preparation and paint, or at the purchaser’s option, hot-dip galvanized in accordance with Specification A 153, or other finish as agreed upon between purchaser and manufacturer.

6.1.1.3 Aluminum Alloy Materials—Housings shall be constructed of aluminum alloy in accordance with Specification B 26, Grade 356-T6 or A 356-T6.
6.1.1.4 Finish for aluminum alloy housings shall be bare, anodized in accordance with Specification B 580 or as otherwise agreed between purchaser and manufacturer.

6.1.1.5 Iron-chromium-nickel, corrosion resistant material: Housings shall be constructed of iron-chromium-nickel alloy in accordance with Specification A 743/A 743M, Grade CF-8 or Grade CF-8M.

6.1.1.6 Finish for iron-chromium-nickel shall be bare or otherwise agreed between purchaser and manufacturer.

6.1.2 Grooved Mechanical Coupling — Gaskets shall be of materials suitable for the intended service. Elastomers shall comply with Classification System D 2000.

6.1.3 Grooved Mechanical Coupling — Bolting:

6.1.3.1 Carbon Steel Material — Bolts shall be in accordance with Specification A 183, Grade 2, Oval Neck. Nuts shall be in accordance with Specification A 194, Grade 2. Finish shall be black or at the purchaser’s option, zinc electroplated to Specification B 633.

6.1.3.2 Corrosion Resistant Material — Bolts shall be in accordance with Specification A 193, Grade B 8, Class 2 (AISI Type 304) or Specification A 193, Grade B 8M, Class 2 (AISI Type 316). Nuts shall be in accordance with Specification A 194 Grade 8.

6.2 Type II—Plain End Mechanical Coupling:

6.2.1 Plain End Mechanical Coupling Housings or Center Sleeves:

6.2.1.1 Cast Ferrous Materials — Cast housings or center sleeves shall be constructed of ductile iron in accordance with Specification A 395 Grade 60–40–18 or 65–45–15, Specification A 536, Grade 65-45-12 or malleable iron in accordance with Specification A 47, Grade 32510 or 35018.

6.2.1.2 Steel Materials — End rings and sleeves made from carbon or stainless steel shall be made from material with a minimum yield strength of 172 MPa (25,000 PSI).

6.2.1.3 Plain end mechanical couplings shall be coated with the manufacturer’s standard preparation and paint or other finish as agreed upon between the purchaser and manufacturer. Finish for iron chromium-nickel parts shall be bare or otherwise agreed upon between purchaser and manufacturer.

6.2.2 Plain End Mechanical Coupling — Gaskets shall be of materials suitable for the intended service (consult manufacturer for recommendation). Elastomer shall comply with Classification System D 2000 or BS 2494.

6.2.3 Plain End Mechanical Coupling — Bolting:

6.2.3.1 Carbon Steel Material — Bolts shall be in accordance with Specification A 183, Grade 2, Oval Neck or Specification A 325—Type 2 Heavy Hex; Cap screws shall be in accordance with Specification A 574 or BS 6104; Female threaded parts, other than nuts, shall be in accordance with Specification A 183, Grade 2; Nuts, if required, shall conform to Specification A 183, Grade 2 or Specification A 563—Grade C3 or DH3, or as otherwise agreed by purchaser and manufacturer. Finish shall be zinc electroplated to Specification B 633 or BS 1706.

6.2.3.2 Corrosion Resistant Material — Bolts or threaded female parts other than nuts shall be in accordance with Specification A 193, Grade B 8, Class 2 (AISI Type 304) or Grade B 8M, Class 2 (AISI Type 316); Cap screws shall be in accordance with F 837 or BS 6105; Nuts, if required, shall be in accordance with Specification A 194, Grade 8 or as agreed upon by purchaser and manufacturer.

6.3 Other Materials — Where other materials are required, the material and mechanical properties of the product shall be as agreed upon by the GMC manufacturer and the purchaser.

6.4 Material Quality:

6.4.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics to meet the performance requirements of this standard.
6.4.2 The manufacturer is encouraged to use materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term “recovered materials” means: “Materials which have been collected or recovered from solid waste and reprocessed to become a source of raw material, as opposed to virgin raw materials.” Used or rebuilt products shall not be used.

7. Other Requirements

7.1 Testing Requirements:

7.1.1 GMC shall be subjected to the tests described in the Annex for the purpose of qualifying the GMC design.

7.1.2 These tests shall be repeated when changes are made in the design, material, or manufacturing process that degrade the performance of the GMC. Degradation determination is to be made by the manufacturer or at agreement between the manufacturer and purchaser.

7.2 Qualification Requirements:

7.2.1 GMC shall be qualified using specimens of the same type, grade and class. Each type, grade, and class shall be tested in order to qualify the design. Qualification of the GMC requires successful completion of required testing. Each GMC design is only qualified for use on the pipe or fitting material and wall thickness on which it was tested.

7.2.2 All GMC’s tested shall be comprised of an equal number of specimens from the smallest, most intermediate size, and largest sizes within the size range of the GMC being qualified.

7.2.3 Through reasonable interpolations between the GMC sizes tested, other sizes of GMC’s within the same type, grade and class will be considered qualified if the specimens according to 7.2.2 pass the testing requirements. Extrapolation shall not be used for qualification purposes.

7.3 Qualification Test Report:

7.3.1 Upon completion of testing, a qualification test report shall be written and maintained on file during the life cycle of the design. A copy of this report shall be made available for inspection at the manufacturer’s facility.

7.3.2 Any failure during qualification testing shall be analyzed and the failure analysis and corrective action shall be included in the qualification test report.

7.3.3 A retest as specified in Section 11 (number of tests and retests) may be allowed when failure to the original joint occurs during qualification testing. When retesting is permitted, the failure analysis and corrective action shall be included in the qualification test report specified in 7.3.1.

7.4 Test Equipment and Inspection Facilities:

7.4.1 Test equipment and inspection facilities shall be of sufficient accuracy and quality to permit performance of required inspections and tests.

7.4.2 Calibration System Requirements—The testing and inspection facilities shall maintain a calibration system for Measuring and Test Equipment (M&TE) in accordance with ANSI Z 540.1 with traceability to the National Institute of Standards and Technology (NIST), or shall maintain a calibration system in accordance with the requirements detailed in BS 5781 Part 1 against standards traceable to National Standards.

7.5 Test Conditions:

7.5.1 Test pressures as specified within each test shall be used.

7.5.2 Fluid used in the testing of GMC shall be water or air, as specified.

7.5.3 Unless otherwise specified herein, GMC shall be tested within the temperature range stated by the type of test being performed.

Note 1—When no temperature is specified within a test, the test shall be conducted at ambient conditions.

7.6 Performance Requirements:

7.6.1 Pass criteria for each test shall require meeting or exceeding the performance requirements specified in each test.

8. Dimensions, Mass, and Permissible Variations

8.1 GMC Dimensions:

8.1.1 Type I GMC dimensions shall be as specified by the manufacturer and shall provide the degree of axial and angular deflection (as applicable) specified by the manufacturer when used on pipe grooved in accordance with ANSI/AWWA C-606, as applicable, or manufacturer’s recommendation(s).

8.1.2 Type II GMC dimensions shall be as specified by the manufacturer. Type II Class 2 shall provide angular deflection as specified by the manufacturer. Type II Class 3 GMC shall provide axial movement and angular deflection as specified by the manufacturer.

9. Workmanship, Finish, and Appearance

9.1 GMC Machined Surfaces:

9.1.1 Machined surfaces shall be free from burrs, cracks, laps, and seams which would affect the suitability for the intended service.

9.1.2 Machined surface finishes shall be as specified by the manufacturer.

9.2 Unmachined Surfaces:

9.2.1 Unmachined surfaces, such as forging or casting surfaces, shall be free from scale, blisters, fins, folds, seams, laps, segregations and cracks which would affect suitability for the intended service.

10. Sampling

10.1 In-process Inspection Sampling of GMC Products:

10.1.1 Inspection samples of GMC being manufactured or processed shall be selected in accordance with ANSI/ASQC Z 1.4. Level of inspection and acceptable quality level (AQL) shall be in accordance with the GMC manufacturer’s quality assurance procedures. Other inspection or sampling plans may be used upon mutual agreement between the manufacturer and the purchaser.

10.2 Lot Acceptance:

10.2.1 Lot acceptance shall be based upon meeting the sampling and pass/fail requirements of ANSI/ASQC Z 1.4. Other inspection or sampling plans may be used upon mutual agreement between the manufacturer and the purchaser.

11. Number of Tests and Retest, for Qualification Testing

11.1 Number of Test Specimens:

11.1.1 Each test shall be performed on specimens as denoted in Table A1.1.
11.2 Replacement of Test Specimens:
11.2.1 When untested specimens are rejected as a result of inferior workmanship or materials, or assembly, the specimens shall be dispositioned in accordance with the manufacturer’s quality assurance procedures.

11.2.1.1 New test specimens of the same type, grade, and class, and pipe or fittings of the same O.D. size and wall thickness shall be prepared in accordance with Section 12.

11.3 Penalty Runs:
11.3.1 In the event of not passing a test, the manufacturer shall proceed with one of the following options:
11.3.1.1 If the leak or separation is determined to be design related, the manufacturer shall redesign the GMC and start all tests from the beginning.
11.3.1.2 If the leak or separation is determined to be unrelated to the design, the test specimen shall be rerun. A replacement test specimen shall be prepared in accordance with the requirement specified in 11.2.
11.3.1.3 If the leak or separation cannot be shown to be either design related or non-design related, the manufacturer shall test three (3) additional penalty specimens. The requirements specified in 11.3.2 shall apply.
11.3.2 Penalty run specimens shall be prepared when GMC has failed any of the tests specified in the Annex.
11.3.2.1 The GMC’s used for penalty run(s) shall be of the same type, grade, and class as the failed GMC being replaced.
11.3.2.2 The pipe or fitting used in penalty runs shall be of the same material, O.D., and wall thicknesses as the pipe or fitting being replaced.
11.3.2.3 Preparation of the penalty run specimens shall be in accordance with Section 12.
11.3.2.4 Penalty run specimens shall be identified in accordance with 12.3 and 11.3.2.5.
11.3.2.5 In addition to the part number and test specimen number, a designator shall be placed after the test specimen number which allows the specimen to be identified as a penalty run specimen. The method used to identify penalty run specimens shall be at the manufacturer’s option.

12. Specimen Preparation
12.1 Specimen Preparation and Installation:
12.1.1 Specimen preparation and installation on appropriate testing apparatus shall be in accordance with the manufacturer’s recommended procedures.
12.2 Assembly of Specimens:
12.2.1 GMC qualified under the requirements of this specification shall be tested and qualified as a completed assembly; that is, joint.
12.2.2 The intermixing of sub-components of the same type, grade, and class, but of different brands or trade name, constitutes non-compliance with this standard.
12.2.3 Test specimens used in testing shall be assembled using a GMC of a single type, grade and class.
12.2.4 The wall thickness and O.D. size of the pipe or fitting shall be as specified for the GMC joint being qualified.
12.3 Identification of Test Specimens:
12.3.1 Each test specimen shall be identified with a unique number to provide traceability back to the test records.
12.3.2 Identification of test specimens shall be permanent. In those cases where size or design does not permit permanent markings, tagging or bagging may be used.
12.3.2.1 When, as a result of testing, a test specimen is sectioned into two (2) or more pieces, each piece shall be marked with the original unique identification number.
12.4 Test specimens may be disposed of following approval of the qualification test report by the GMC manufacturer.

13. Test Methods
13.1 Standard Qualification Tests for GMC shall be as specified in the Annex. The following tests described herein are required for GMC qualification as applicable to the type, grade and class.

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</tr>
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13.2 Certification of Test Results:
13.2.1 When specified in the purchase order or the contract, the purchaser shall be furnished certification that samples representing the GMC have been tested as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the results shall be available for inspection at the manufacturer’s facility.

13.3 In-Process Material Tests—In-Process Material Tests shall be performed in accordance with manufacturer’s standard in-process test procedures.

14. Inspection
14.1 Terms of Inspection:
14.1.1 Inspection of GMC shall be in accordance with manufacturer’s standard inspection procedure or as agreed upon between the purchaser and the manufacturer or supplier as part of the purchase contract.
14.2 Raw Material Inspection:
14.2.1 Raw material shall be inspected for compliance with its material specification. A certificate of compliance or mill certificate shall be obtained from the material supplier, as applicable.
14.3 Quality Conformance Inspection:
14.3.1 GMC samples shall be visually and dimensionally examined to verify compliance with the manufacturer’s appropriate drawings.
14.4 Process Control Inspection:
14.4.1 GMC shall be inspected throughout the entire manufacturing and processing cycle. Methods of inspection shall be in compliance with manufacturer’s quality assurance procedures.
14.5 Inspection Records:
14.5.1 Inspection records shall be maintained by the manufacturer. The length of time on file shall be in accordance with the manufacturer’s quality assurance procedures.

15. Certification

15.1 Certification of Testing (see 13.2).

15.2 Certification of Material.

15.2.1 A certificate of compliance shall be obtained from the material supplier, when applicable. This certificate shall state that applicable requirements for the raw material have been met. As a minimum, the material specification shall specify the chemical and mechanical requirements of the material, as applicable.

16. Product Marking

16.1 Product Marking:

16.1.1 Each GMC shall be marked with the manufacturer’s name or trademark, size, and markings traceable to the type, grade and class. When shape or size does not permit inclusion of all required markings, the information may be omitted in the reverse order presented.

16.2 Additional Markings:

16.2.1 When specified in the contract or purchase order, additional markings other than those specified shall be applied, provided purchaser and supplier have agreed upon such prior to issuance of the contract or purchase order.

17. Packaging

17.1 The GMC shall be boxed, crated, wrapped and otherwise protected during shipment and storage in accordance with manufacturer’s standard practice. Care shall be taken to properly protect the GMC from distortion and other damage during shipment and storage. GMC’s may be shipped assembled; or bolts and gaskets may be packaged separately in suitable containers to withstand handling and storage.

18. Keywords

18.1 coupling; flexible; gasketed; grooved; plain end; rigid

ANNEXES

(Mandatory Information)

A1. PERFORMANCE TESTS FOR GMC

A1.1 Scope

A1.1.1 This section lists the tests to be used in the qualification of GMC. In addition, statements that apply to all tests are specified to minimize redundancy.

A1.1.2 The values stated in acceptable metric units are to be regarded as standard. The values given in parentheses (inch/pound) are provided for information purposes only.

A1.1.3 The tests required to qualify GMC may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulations/limitations prior to use.

A1.1.4 The test procedures appear in the following order:

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A1.1.5 The sections listed below are from the main body of this standard and apply to the test specimens used in the performance of the tests listed in A1.1.4.

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A1.3.5 When pressure testing with water, test specimens shall be purged of air prior to pressurizing.

A1.3.6 End caps, adapters, and plugs used to block off a pipe or fitting end shall be of design(s) designated by the manufacturer. The end caps, adapters, and plugs shall be constructed to preclude their failure during testing.

A1.3.7 Failure of any test specimen which is related to separation or leakage at the end cap, adapter or pipe/fitting shall be recorded in the test report, but shall not be considered a failure of the GMC pipe or fitting combination being tested. Replacement test specimens shall be prepared in accordance with Section 12.

A1.3.8 Failure of any test specimen at the GMC pipe or fitting joint being proof tested constitutes failure of the GMC design.

A1.3.9 GMC shall be assembled in accordance with manufacturer’s recommended procedures.

A1.3.10 Qualification of GMC shall be based upon a successful passing of the tests described in Annex A2 through Annex A10. The flexibility test (see Annex A6) does not apply to Class 1 GMC’s, the rigidity test (see Annex A8) does not apply to Class 2 and 3 GMC’s and the bending moment proof test (see Annex A9) does not apply to Type II Class 2 or 3 GMC’s.

A1.4 Precision and Bias

A1.4.1 No statement is made about either the precision or bias of Section A1 “Performance Tests for GMC” since this section contains general information only.

A2. EXAMINATION OF SPECIMEN

A2.1 Scope

A2.1.1 This procedure covers the inspection and examination of test specimens prepared in accordance with the requirements specified in Section 12.

A2.2 Significance and Use

A2.2.1 GMC’s are comprised of couplings which are attached to or onto pipes or fittings using a variety of methods. In order to ascertain the integrity of each GMC type covered, it becomes important to subject all types of GMC to essentially the same tests. When the same tests are used, the assembly of some of the test specimens may become critical to the results of the test performed. The usefulness of this procedure lies in the examination of GMC test specimens to ensure that resulting assemblies duplicate appropriate stresses for all types of GMC qualified using the tests specified herein.

A2.3 Procedure

A2.3.1 GMC test specimens shall be assembled in accordance with the manufacturer’s assembly procedures.

A2.3.2 The materials used to assemble the test specimens shall be in accordance with Section 12. The pipe or fitting dimensions may vary (tolerances), as allowed by the manufacturer.

A2.4 Precision and Bias

A2.4.1 Precision is based upon the accuracy of the GMC dimensions in accordance with applicable drawings. The pipe or fitting used in conjunction with GMC shall be in accordance with specification(s) recommended by the manufacturer. There may be bias for the examination of specimen based upon the human elements involved in the visual inspection and measurement methods used.
A3. PNEUMATIC PROOF TESTING

A3.1 Scope
A3.1.1 This section covers pneumatic proof testing of GMC test specimens.

A3.2 Significance and Use
A3.2.1 This test is the initial test of all GMC specimens prepared for qualification. The test is performed by internally pressurizing the test specimen(s) using dry air or nitrogen (N\textsubscript{2}). A pressure of .55 MPa (80 psi) is applied. If the specimen shows no evidence of leakage, the specimen has successfully passed the test. This test is useful in determining if the GMC pipe or fitting connection has been assembled correctly, if the gasket is seated and installed correctly, and if the GMC design performs as proposed at this pressure.

A3.3 Procedure of Test
A3.3.1 The test specimen shall be placed in an appropriate chamber and secured in place in accordance with the manufacturer’s recommended procedures. Classes 1 and 2 shall not be longitudinally restrained. Class 3 shall be longitudinally restrained.

A3.3.2 The chamber shall be equipped with calibrated pressure gages (see A1.3.3) to permit visual readings of the actual internal pressure being applied.

A3.3.3 The pneumatic proof test shall be performed at ambient (see A1.3.2) temperature.

A3.3.4 Nitrogen (N\textsubscript{2}) or dry air shall be used to internally pressurize the test specimens to .55 MPa \textpm .03 MPa (80 psi \textpm 4.3 psi). A stabilization period shall be allowed to remove surface bubbles. The test period following stabilization shall be five minutes. There shall be no evidence of leakage during the test period. If leakage occurs during the test period, the test shall be discontinued and the affected specimens shall have failed the test. The test report shall be filled out noting the reason for discontinuing the test (see A1.3.7 and A1.3.8 for further information).

Method 1

The test joint shall be completely submerged in water (H\textsubscript{2}O) prior to beginning the test. Uppermost portion of GMC shall be no more than one foot below the surface of the water.

A3.3.6 If there is no evidence of leakage during the test period, the test specimens shall have passed the pneumatic proof test. If specimens do not pass this test, proceed per Section 11.

A3.4 Precision and Bias
A3.4.1 The precision of this test is the calibrated accuracy of the pressure gages. The gage(s) used to measure the internal pressure applied shall be calibrated to \textpm 1 \% throughout the range shown on the gage(s). There shall be no bias for Annex A3. Pneumatic Proof Testing, as the allowable test pressure tolerances of \textpm .03 MPa (4.3 psi) are well above the range of accuracy required to attain accurate readings.

A4. VACUUM PROOF TEST

A4.1 Scope
A4.1.1 This section covers Vacuum Proof Test of GMC test specimens.

A4.2 Significance and Use
A4.2.1 This test is performed by drawing an internal vacuum in the GMC test specimen, isolating the GMC by closing shut off valves and checking for loss of vacuum. The vacuum is internally applied to the assembled specimen to determine if it can maintain specified vacuum. If the specimen shows no loss of vacuum after 5 minutes, it shall pass the test.

A4.3 Procedure of Test
A4.3.1 The test specimen shall be placed in an appropriate test area and secured in place in accordance with the manufacturer’s recommended practice. Classes 1 and 2 shall not be longitudinally restrained. Class 3 shall be longitudinally restrained.

A4.3.2 The test set up shall be equipped with a calibrated vacuum gage(s) to permit visual readings of the actual vacuum being applied.

Method 2

Where submersion under water is impractical, leak detection using a soap type leak detecting fluid may be substituted.

A4.3.4 The pneumatic proof test shall be performed at ambient (see A1.3.2) temperature.

A4.3.5 Nitrogen (N\textsubscript{2}) or dry air shall be used to internally pressurize the test specimens to .55 MPa \textpm .03 MPa (80 psi \textpm 4.3 psi). A stabilization period shall be allowed to remove surface bubbles. The test period following stabilization shall be five minutes. There shall be no evidence of leakage during the test period. If leakage occurs during the test period, the test shall be discontinued and the affected specimens shall have failed the test. The test report shall be filled out noting the reason for discontinuing the test (see A1.3.7 and A1.3.8 for further information).

A4.3.6 If there is no evidence of leakage during the test period, the test specimens shall have passed the pneumatic proof test. If specimens do not pass this test, proceed per Section 11.
A4.4 Precision and Bias

A4.4.1 The precision of this test shall be the calibrated accuracy of the vacuum gages. The gage(s) used to measure the vacuum applied shall be calibrated to ±1 % or better throughout the range shown on the gage(s). There shall be no bias for A4 Vacuum Test, as the allowable vacuum tolerances of ±5 % are well above the range of accuracy required to attain accurate readings.

A5. HYDROSTATIC PROOF TESTING

A5.1 Scope

A5.1.1 This section covers hydrostatic proof testing of GMC test specimens.

A5.2 Significance and Use

A5.2.1 This test is performed by internally pressurizing the test specimens using water. The initial pressure applied, .690 MPa (100 psi), tests the assembled specimen to determine if it can retain fluid without wetting of the external surface or leakage at the GMC joint. If there is no leakage, the pressure is gradually increased to 150 % of the proposed rated pressure of the pipe or fitting GMC joint. This elevated pressure level tests the ability of the specimens to hold fluid without wetting of the surface, and not to leak or fail structurally. Holding time for this pressure test shall be 10 min.

A5.2.2 If the specimen still shows no evidence of leakage after this test, the specimens shall pass the test. This test is useful in determining the integrity of the fitting joint to hold fluid at an elevated pressure without any wetting of the surface or leakage. After successful completion of this test, the test specimens are ready for additional testing (see Table Test Sequence).

A5.3 Procedure of Test

A5.3.1 Test specimens shall be installed onto an appropriate testing apparatus, filled with water and purged of all air.

A5.3.2 The test specimens shall be placed in a burst chamber and secured into place in accordance with the manufacturer’s recommended procedures. Class 1 and 2 GMC shall be tested with no longitudinal restraint provided by the test operator. Class 3 GMC shall be longitudinally restrained.

A5.3.3 The chamber shall be equipped with calibrated pressure gages (see A1.3.3) to permit visual readings of actual internal pressure being applied.

A5.3.4 The hydrostatic proof test shall be performed at ambient temperature (see A1.3.2).

A5.3.5 The test specimens shall be initially pressurized to .690 MPa (100 psi) ± .03 MPa (4.3 psi) for a total period of 5 min. There shall be no evidence of wetting of the surface or leakage during this 5-min period. If wetting of the surface or leakage occurs, the test shall be discontinued and the affected specimens shall fail the test. Proceed per Section 11.

A5.3.6 If there is no evidence of leakage after the initial 5 min period, the internal pressure shall be gradually increased at a rate not to exceed 138 MPa/min (20 000 psi/min) to 150 % ± 5 % of the proposed rated pressure of the pipe or fitting GMC joint. This pressure shall be maintained for an additional period of 10 min. There shall be no evidence of wetting of the external surface or leakage during this 10-min period. If wetting of the surface or leakage occurs, the test shall be discontinued and the affected specimens shall fail the test. Proceed per Section 11.

A5.3.7 If there is no evidence of wetting of the external surface or leakage within the fitting area or joint during both pressurized periods, the test specimens shall pass the hydrostatic proof test.

A5.4 Precision and Bias

A5.4.1 The precision of this test shall be the calibrated accuracy of the pressure gages. The gages used to measure the pressures applied shall be calibrated to ±1 % or better throughout the range shown on the gages. There shall be no bias for A5 hydrostatic proof test, as the allowable tolerances (±5 %) are well above the range of accuracy required to attain accurate readings during both pressurized periods.

A6. FLEXIBILITY PROOF TEST

A6.1 Scope

A6.1.1 This section covers flexibility proof testing of Types I & II Class 2 and Type II Class 3 GMC.

A6.2 Significance and Use

A6.2.1 The significance of this test is to verify the axial pipe and angular pipe movement available with Types I & II Class 2 and Type II Class 3 couplings.

A6.2.1.1 Type I Class 2—The test for axial movement is performed by assembling the GMC with the pipe or fitting ends fully inboard and then pressurized to extend the joint to its furthest extended position. The test for angular movement is performed by applying bending moment from Table A6.1 (see Note 2) to the joint and measuring the resultant angular deflection.

A6.2.1.2 Type II Class 2—The test for angular movement is performed by filling and pressurizing the GMC with water to the proposed working pressure, then deflecting the joint to the test angle. The test angle shall be the maximum deflection angle specified by the manufacturer. No leakage shall be allowed during or after this deflection. No permanent damage shall occur to the GMC.

A6.2.1.3 Type II Class 3—The test for axial movement shall be performed by assembling the GMC in accordance with the manufacturer’s instructions. The joint shall then be pressurized...
to its proposed working pressure, while allowing the pipe to move longitudinally to the maximum allowable movement specified by the manufacturer. No leakage shall be allowed during or after this movement. The test for angular movement shall be performed by assembling the GMC with the pipe in the deflected position, and filling and pressurizing with water to the working pressure. The deflection angles shall be as recommended by the manufacturer.

A6.3 Procedure of Test

A6.3.1 Type I Class 2—Pipe shall be grooved (roll or cut as applicable) in accordance with ANSI C 606 as applicable or manufacturer’s recommendation(s) and a line scribed 1 in. from each groove away from pipe end. The GMC shall be assembled with the pipe ends touching or as fully inboard as the GMC permits. The distance between the two scribe lines shall be measured and recorded. The specimen shall not be longitudinally restrained. The specimen shall be filled with water and pressurized to .69 MPa (100 psi) or 25 % of GMC proposed rating, whichever is larger. The new distance between the scribe lines shall be measured and recorded. The difference between the two scribe line measurements is the measured axial movement. The test for angular movement consists of applying a small bending moment per Table A6.1 (see Note 2) to the same assembled specimen from above with no internal pressure and measure the total deflected angle achieved. The angle shall be measured using an inclinometer or by measuring the deflection and distance between the support points and calculating the angle.

A6.3.2 Type II Class 2—Prepare the pipe in accordance with the coupling manufacturer’s recommendations. The test shall be performed by assembling the GMC onto the pipe, filling and pressurizing with water to the proposed working pressure, and deflecting the joint to the test angle. The test angle shall be the maximum deflection angle specified by the manufacturer. No damage to the GMC or leakage shall be allowed during the test. Holding time for this test shall be no less than 10 min. The deflection angle shall be measured using an inclinometer or by measuring the deflection and distance between the support points and calculating the angle.

A6.3.3 Type II Class 3—The pipe shall be prepared in accordance with the coupling manufacturer’s recommendations. The GMC shall be assembled with pipes at their most in-board position. A line shall be scribed 1 in. from the outside of the coupling on each pipe. The distance between the two scribed lines shall be measured and recorded. The specimen shall be pressurized and filled with water to its working pressure. The restraint on the pipe shall be adjusted to provide 10 mm (3⁄8 in.) of total longitudinal movement for 254 mm (10 in.) and larger pipe. Smaller size shall be tested in accordance with manufacturer’s published limits. No leakages shall be allowed during this test. Movement shall be determined by measuring between the two scribed lines and subtracting the original line spacing. The test for angular movement shall be performed by assembling the GMC with the pipe in the deflected position, and filling and pressurizing with water to the working pressure. The deflection angles shall be the maximum deflection angle specified by the manufacturer. No leakage shall be allowed when the GMC is pressurized. The data for this test shall be recorded and used for future reference. The test shall be repeated for each possible combination of pipe and coupling to ensure consistency and accuracy.

### Notes

1. For sizes and wall thicknesses not listed.
2. Use 10 % of Moments listed for flexibility tests.
3. Use 25 % of Moments listed for rigidity tests.
4. Values in table are for NFPA 13 Hanger Spacing.

### Table A6.1 Bending Moments for Flexibility (Note 2) Rigidity (Note 3) and Proof Test Pipe Schedule

<table>
<thead>
<tr>
<th>Nominal Size (NPS)</th>
<th>STEEL NPS</th>
<th>AWWA</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>N.M.</td>
<td>N.M.</td>
</tr>
<tr>
<td></td>
<td>(Lb.-Ft.)</td>
<td>(Lb.-Ft.)</td>
</tr>
<tr>
<td>1 1⁄2</td>
<td>358</td>
<td>264</td>
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<td>1039</td>
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<td>14</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>16</td>
<td>. . .</td>
<td>. . .</td>
</tr>
</tbody>
</table>

**METHOD FOR CALCULATING TEST MOMENT**

\[ M = F (L) \]

- **F** = Weight of Pipe + Weight of Water
- **L** = \( \frac{1}{2} \) (Hanger Spacing)

EX: For 2\(^{nd}\) Schedule 40 steel pipe with NFPA Hanger Spacing where \( L = 7\frac{1}{2} \) ft

\[ F = 3.653 (15) + 40.27 (15) (0.36) \]

Where 3.653 is the pounds per foot of 2\(^{nd}\) Schedule 40 pipe, 40.27 is the cubic inches of water per foot of 2\(^{nd}\) Schedule 40 pipe, .036 is the pounds per cubic inch of water, 15 is total length of pipe in feet.

\[ F = 54.796 + 21.746 = 76.542 \text{ pounds} \]

**NOTE 2**—For sizes and wall thicknesses not listed.
A6.3.4 The flexibility proof test shall be performed at ambient temperature (see A1.3.2).

A6.4 Precision and Bias

A6.4.1 The precision of this test shall be the calibration accuracy of the measuring equipment. The calipers used to measure the movement shall be calibrated to .03 mm (.001 in.) throughout its range. The inclinometer shall be zeroed prior to each reading. The accuracy of the readings is dependent solely on the ability to read the scales typically ±1°. There may be bias for the examination of the movement based upon the human elements involved in the visual inspection used.

A7. HYDROSTATIC BURST TEST

A7.1 Scope

A7.1.1 This section covers the test requirements for burst testing.

A7.2 Significance and Use

A7.2.1 This test verifies the mechanical integrity of the pipe or fitting and GMC to withstand, without leakage or burst, a minimum pressure equal to three times the proposed rated pressure of the pipe or fitting and GMC, which form a joint. To successfully pass this test, the pipe or fitting and GMC shall not leak or burst.

A7.3 Procedure of Test

A7.3.1 Test specimens shall be filled with water prior to installation onto the appropriate testing apparatus and purged of entrapped air.

A7.3.2 The test specimens shall be placed in a burst chamber. Class 1 and 2 GMC shall not be longitudinally restrained.

A7.3.3 The chamber shall be equipped with calibrated pressure gages (see A1.3.3) to permit visual readings of actual pressure being applied.

A7.3.4 The hydrostatic burst test shall be performed at ambient temperature (see A1.3.2).

A7.3.5 Class 1 test specimens shall be subjected to a gradual increase of pressure at a rate not to exceed 138 MPa/min to three times the proposed rated pressure of the specimen assembly. If leakage or burst occurs below three times the proposed rated pressure of the specimen assembly, the test shall be discontinued and the affected test specimens shall fail the test for the proposed rating. The test report shall be filled out noting the reason for discontinuing the test. See A1.3.4 or A1.3.5 for further information. If there is no evidence of leakage or burst when three times the proposed rated pressure of the specimen assembly is attained, the pressure shall be gradually increased until burst occurs. The test specimens have passed the hydrostatic burst test when three times the proposed rated pressure of the specimen assembly has been attained. Pressure attained at the time of burst shall be recorded in the Qualification Test Results.

A7.3.6 For Class 2 and Class 3 GMC’s, the specimen shall be mounted in a test fixture such that the joint is held fixed at its maximum angular deflected position (determined from the test in Annex A6). This test specimen shall then be subjected to a gradual increase of pressure at a rate not to exceed 138 MPa/min (20 000 psi/min) to three times the proposed rated pressure of the specimen assembly. If leakage or burst occurs before three times the proposed rated pressure of the specimen assembly, the test shall be discontinued and the affected test specimens shall fail the test for the proposed rating. If there is no evidence of leakage or burst when three times the proposed rated pressure of the specimen assembly is attained, the pressure shall be gradually increased until burst occurs. The test specimens have passed the hydrostatic burst test when three times the proposed rated pressure of the specimen assembly has been attained. Pressure attained at the time of burst shall be recorded in the Qualification Test results.

A7.4 Precision and Bias

A7.4.1 The precision of this test shall be the calibrated accuracy of the pressure gages. The gages used to measure the pressures applied shall be calibrated to ±1 % or better throughout the range shown on the gages. There may be bias in this test if the pipe or fitting selected bursts below three times its proposed rated pressure. If this occurs, the test specimens may be replaced in accordance with A1.3.7. There also may be bias based upon the human elements involved in the visual inspection used.
A8. RIGIDITY PROOF TEST

A8.1 Scope

A8.1.1 This section covers rigidity proof testing of Class 1 GMC specimens.

A8.2 Significance and Use

A8.2.1 The significance of this test is to demonstrate the suitability of the GMC for use when the piping system is supported as a rigid system. The test is performed by applying a moment to the specimen equal to the maximum moment generated by the pipe when filled with water and supported at the maximum allowable hanger spacing (see Table A6.1, Note 3). The GMC is to be pressurized with water to its rated pressure during application of the bending moments. The GMC shall pass this test if the included angle of the pipe sections adjacent to the GMC does not change by more than angle $\Theta$ with the test moment applied at the GMC, and there is no evidence of leakage.

$$\Theta = 60' \text{ (minutes)} - [2' \text{ (minutes)} \times (\text{nominal pipe size in inches})].$$

A8.3 Procedure of Test

A8.3.1 The test shall be conducted with a specimen using test pipe not less than .38 m (15 in.) in length. The support points for the pipe shall be not less than .305 m (12 in.) from the GMC. The test load may be applied directly to the GMC or to the pipe adjacent to the GMC with appropriate load adjustment. The joint shall be internally pressurized to the proposed rated pressure ($\pm$ 5 %) of the GMC pipe or fitting (specimen), whichever is lower. The initial included angle shall be measured and recorded. Do not apply any bending moment while measuring the initial angle. The bending moment listed in Table A6.1 shall be applied (see Note 3) to the joint. The final included angle shall then be measured and recorded. The deflection angle shall be determined either by measuring the movement of the GMC and calculating the angle or by direct measurement. The test shall be conducted at ambient temperature (see A1.3.2). If there is no evidence of leakage and the included angle has not changed more than angle $\Theta$, the GMC shall pass the test. $\Theta$ shall be calculated as follows: $\Theta = 60' \text{ (minutes)} - [2' \text{ (minutes)} \times (\text{nominal pipe size in inches})].$

A8.4 Precision and Bias

A8.4.1 The precision of this test shall be the calibrated accuracy of the pressure gages and the accuracy of the reading of the inclinometer or dial gage. The gages used to measure the pressure applied shall be calibrated to $\pm 1 \%$ or better throughout the range used for the test. The inclinometer shall be zeroed prior to each reading. Therefore, the accuracy of the readings is dependent solely on the ability to read the scales, typically $\pm 1 \%$. There may be bias for the visual reading of the inclinometer or dial gage based upon the human elements involved in the visual reading of the meter(s).

A9. BENDING MOMENT PROOF TEST

A9.1 Scope

A9.1.1 This section covers the bending moment proof test for Type I Class 1 and 2 and Type II Class 1 GMC specimens.

A9.2 Significance and Use

A9.2.1 This test verifies the ability of the GMC to resist a bending moment equal to the bending moment generated by the pipe when filled with water, supported at one side of the GMC by a hanger and with the next hanger broken on the maximum allowable hanger spacing. The GMC is to be pressurized to its proposed rated pressure $\pm 5 \%$ during the test. The GMC shall have passed this test if it withstands this moment without failing and no evidence of leakage is observed.

A9.3 Procedure for Test

A9.3.1 The test shall be conducted with a specimen using test pipe at least .38 meters (15 inches) in length. The support points for the pipe shall be a minimum of .305 meters (12 inches) from the GMC. The test load may be applied directly to the GMC or on the pipe adjacent to the GMC. In either case, the applied load shall be such that the test moment acts at the GMC. The joint shall be pressurized to the proposed rated pressure ($\pm 5 \%$) of the specimen. The moment (see Table A6.1) shall be applied to the joint and held for not less than one minute. The test shall be conducted at ambient temperature (see A1.3.2). If the GMC withstands this moment and shows no evidence of leakage, it shall pass this test.

A9.4 Precision and Bias

A9.4.1 The precision of this test shall be the calibrated accuracy of the pressure gages and the accuracy of the reading of the inclinometer or dial gage. The gages used to measure the pressure applied shall be calibrated to $\pm 1 \%$ or better throughout the range used for the test. There is no bias for this test because the allowable tolerance of $\pm 5 \%$ is well above the range of accuracy required to attain accurate readings.
A10.1 Scope
A10.1.1 This section covers the bending moment ultimate test for Type I Class 1 and 2 and Type II Class I GMC specimens.

A10.2 Significance and Use
A10.2.1 This test verifies the safety factors available in the GMC when tested with the bending moment from Annex A8 and Annex A9. This test is performed by pressurizing the specimen to its proposed rated pressure and then applying a bending moment to cause failure. The pressure is maintained at the proposed rated pressure throughout the test. The test is conducted at ambient temperature (see A1.3.2). A specimen that withstands two times the bending moment for Annex A9 without failure has passed this test.

A10.3 Procedure for Test
A10.3.1 The test shall be conducted with a specimen using test pipe not less than .38 meters (15 inches) in length. The support points for the pipe shall be not less than .305 meters (12 inches) from the GMC. The test load may be applied directly to the GMC or on the pipe adjacent to the GMC. In either case, the applied load shall be such that the described test moment acts at the GMC. This test shall be conducted at ambient temperature (see A1.3.2). The joint shall be internally pressurized to the proposed rated pressure (±5 %) of the specimen. Increasing moments shall be applied to the GMC while maintaining the internal pressure at the proposed rated pressure until failure occurs. This bending moment shall be applied at a rate not to exceed 27,116 Newton meters (20,000 Ft-Lbs) per minute. GMCs that withstand two times the test moment from Annex A9 without evidence of leakage shall pass the test. The moment at failure shall be recorded.

A10.4 Precision and Bias
A10.4.1 The precision of this test shall be the calibrated accuracy of the pressure gages. The gages used to measure the pressure applied to the specimen and to the bending apparatus, as applicable, shall be calibrated to ±1 % or better throughout the range used for the test. There is no bias for this test because the allowable tolerance of ±5 % is well above the range of accuracy required to attain accurate readings.

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Standard Specification for
Surge Suppressors for Shipboard Use

This standard is issued under the fixed designation F 1507; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard establishes performance requirements of
surge suppressors for use on shipboard ac power circuits.

1.2 Surge suppressor shall be a protective device for limit-
ing voltage transients on equipment by discharging, dissipating
internally, bypassing surge current, or a combination thereof
and which prevents continued flow of follow current to ground
and is capable of repeating these functions.

1.3 Surge suppressors covered by this specification may
consist of a single circuit element or may be a hybrid device
using several suppression devices.

2. Referenced Documents

2.1 The following documents of the issue in effect on the
date of material purchase form a part of this specification to the
extent referenced herein:

2.2 American National Standards:²
ANSI/IEEE Std 4 IEE Standard Techniques for High
Voltage Testing
ANSI/IEEE C62.41 Recommended Practice on Surge Volt-
age in Low-Voltage AC Power Circuits
Connected to Low-Voltage AC Power Circuits
ANSI/IEEE C84.1 Electrical Power Systems and
Equipment—Voltage Ratings

2.3 Military Standard:³
MIL-STD-1399 Section 300; Military Standard Interface
Standard for Shipboard Systems, Section 300, Electric
Power, Alternating Current

2.4 Underwriters Laboratories Standard:⁴
UL 1449 Transient Voltage Surge Suppressors, 2nd Edition

3. Terminology

3.1 Definitions:

NOTE 1—These definitions other than specific to the standard are taken
from UL 1449, ANSI/IEEE C62.41, and MIL-STD 1399 to provide for
harmonization of terms.

3.2 power interface—The electrical points where the surge
suppression device is electrically connected to the ac power
system.

3.3 combination wave—A surge delivered by an instrument
that has the inherent capability of applying a 1.2/50-µs voltage
wave across an open circuit and delivering an 8/20-µs current
wave into a short circuit. The exact wave that is delivered is
determined by the instantaneous impedance to which the
combination wave is applied. (Also called combination
voltage/current surge or combination V/I surge.)

3.4 crest (peak) value (of a wave, surge or impulse)—The
maximum value that a wave, surge, or impulse attains.

3.5 electric power source—The electric power that is sup-
plied for testing.

3.6 electric power system ground—Ground is a plane or
surface used by the electric power system as a common
reference to establish zero potential. Usually, this surface is the
metallic hull of the ship. On a nonmetallic hull ship, a special
ground system is installed for this purpose.

3.7 follow (power) current—The current from the connected
power source that flows through a surge protective device
following the passage of discharge current.

3.8 frequency tolerance—Frequency tolerance is the max-
imum permitted departure from nominal frequency during
normal operation, excluding transient and cyclic frequency
variations. This includes variations such as those caused by
load changes, switchboard frequency meter error, and drift.
Unless specified otherwise, frequency tolerance shall be con-
sidered to be ±10 % of nominal frequency.

3.9 inrush current—The inrush current is a sudden change
in line current that occurs during startup or as a result of a change
to the operating mode. Inrush current is dependent on
the type of load connected to the surge suppressor, and
typically will rise to a maximum value in a few milliseconds
and decay to rated value in several milliseconds to several
seconds.
3.10 leakage current—Line current drawn, either line-to-line or line-to-ground, by the suppressor when operated at the maximum continuous operating voltage.

3.11 maximum continuous operating voltage—Maximum sinusoidal rms voltage which may be continuously applied without degradation or deleterious effects.

3.12 measured limiting voltage—The crest (peak) value of the voltage measured at the leads, terminals, receptacle contacts and the like, intended for connection to the load(s) to be protected, and resulting from application of a specified surge.

3.13 nominal frequency—the nominal frequency is the designated frequency in Hz.

3.14 nominal system voltage—A nominal value assigned to designate a system of a given voltage class in accordance with ANSI/IEEE C84.1. For the purpose of this standard, nominal system voltages are 120, 208, 240, and 480 vac. All voltages in this standard are root-mean-square (rms) unless stated otherwise. All tolerances are expressed in percent of the nominal system voltage.

3.15 one-port transient voltage surge suppressor—A TVSS having one set of electrical connections (terminals, leads and the like) intended only for shunt-connection to the ac power circuit, such that load current in the ac power circuit bypasses the TVSS.

3.16 peak overshoot voltage—Maximum voltage above the voltage protection level (peak voltage minus suppression voltage rating) across the suppressor output terminals during initial response to a voltage spike.

3.17 rated rms voltage (varistor)—Maximum continuous sinusoidal rms voltage which may be applied to a varistor.

3.18 response time (varistor)—The time between the point at which the wave exceeds the voltage protection level (suppression voltage rating) and the peak of the voltage overshoot. For the purpose of this definition, voltage protection level is defined with an 8/20-µs current waveform of the peak current amplitude as the waveform used for this response time.

3.19 secondary surge arrester—A surge protector device acceptable ahead of the service entrance equipment on circuits not exceeding 1000-V rms (location category C as described in ANSI/IEEE C62.41).

3.20 surge—A transient overvoltage superimposed on the ac power circuit. A voltage surge is generally one in which the superposition of the surge and normal power frequency voltage involves peak voltage levels of twice or more the normal voltage of the ac power system and generally lasting not more than one-half period of the nominal system voltage waveform.

3.21 surge protective device (SPD)—A protective device composed of any combination of linear or non-linear circuit elements and intended for limiting surge voltages on equipment by diverting or limiting surge current; it prevents continued flow of follow (power) current and is capable of repeating these functions as specified.

3.22 temporary overvoltage (TOV)—A voltage swell from a sudden change in voltage which goes outside the voltage tolerance limits but does not exceed 120 % of nominal system voltage and returns to and remains within these limits within 2 s after the initiation of the disturbance.

3.23 transient voltage surge suppressor (TVSS)—A surge protective device intended for connection electrically on the load side of the main overcurrent protection in circuits not exceeding 600 V. (Location Categories A and B as described in ANSI/IEEE C62.41.)

3.24 two-port transient voltage surge suppressor—A TVSS having one set of electrical connections (terminals, leads and the like) intended for connection to the ac power circuit and one or more separate sets of electrical connections (terminals, leads, outlet receptacles, and so forth) intended for connecting the load(s) to be protected. This device is series-connected such that load current will flow through the transient voltage surge suppressor.

3.25 voltage drop—Voltage differential measured from input terminals to output terminals under conditions of rated load current for two-port surge suppressors.

3.26 voltage protection level—A suppression rating (or ratings) in volts or kilovolts, selected by the manufacturer that is based on the measured limiting voltage determined during surge testing. Also referred to as the suppression voltage rating.

3.27 voltage spike—A voltage spike is a voltage change of very short duration (100 µs to ½ cycle). The standard 1.2/50-µs lightning impulse, as defined by ANSI/IEEE Std 4, is the characteristic voltage spike used for test purposes.

3.28 voltage tolerance—Voltage tolerance is the maximum permitted departure from nominal system voltage during normal operation, excluding transient voltage variations. Voltage tolerance includes variations such as those caused by load changes, switchboard meter error, and drift. Unless otherwise specified, voltage tolerance shall be considered to be ± 10 % of nominal system voltage.

4. Classification

4.1 Surge suppressors covered in this specification shall be classified by class and type.

4.2 The two classes of surge suppressors covered in this specification are based on and reflect ANSI/IEEE C62.41 locations.

4.2.1 Class A—Surge suppressor associated with long circuit branch that being greater than 30-ft cable distance from the distribution panel and usually installed as a series-connected TVSS at the distribution system receptacle (wall outlet).

4.2.2 Class B—Surge suppressor for short branch circuit, either installed at loads within 30-ft cable distance from the circuit breaker distribution panel or within the distribution panel.

4.3 Type designations for surge suppressors covered in this specification are as follows:

4.3.1 Type I; Permanent Connected Type—A suppressor designed for hard-wired or panel-mounted applications. This type surge suppressor is the only one-port-type TVSS.

4.3.2 Type II; Plug-In Type—A suppressor provided with blades for direct connection at a receptacle and with integral output receptacle(s). By nature of its design, a plug-in suppressor is inserted into the circuit as a series connection.

4.3.3 Type III; Cord-Connected Type—A suppressor that is connected to a receptacle through a flexible cord that is permanently attached to the suppressor device. The cord shall
be in accordance with requirements of UL 1449. Cord-connected devices shall not have means for permanent mounting.

4.3.4 **Type IV: Power Director (Power Center) Type**—A suppressor unit with two-pole main circuit breaker, a master switch for controlling all receptacle outlets, and individual switches for controlling all outlets.

5. **Ordering Information**

5.1 Orders for suppressors under this specification shall include the following:

5.1.1 This specification number;
5.1.2 Nominal system voltage—120, 208, 240, and 480 V;
5.1.3 Frequency—50, 60, and 400 Hz;
5.1.4 Service—single-phase, three-phase delta, three-phase wye;
5.1.5 Load current;
5.1.6 Surge suppressor—class and type;
5.1.7 Protection modes;
5.1.8 Voltage protection level (suppression rating), if known;
5.1.9 Quantity;
5.1.10 Testing requirements—include only if tests other than the production tests required by this specification are to be performed;
5.1.11 Certification requirements; and
5.1.12 Packaging and shipping requirements.

6. **Materials and Manufacture**

6.1 **Materials**—All materials used in the construction of these surge suppressors shall be of a quality suitable for the purpose intended and shall conform to the requirements of this specification.

6.1.1 All metallic enclosures shall be either painted or coated with corrosion resistant material.

6.2 **Manufacture**—Plastic, when used, shall be a suitable thermoplastic or thermoetting material so molded as to produce a dense solid structure, uniform in texture, finish, and mechanical properties.

7. **Requirements**

7.1 **Performance Requirements**:

<table>
<thead>
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<th>Requirement</th>
<th>Specification</th>
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<td>110 % of nominal voltage</td>
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<tr>
<td>Temporary overvoltage withstand (V)</td>
<td>120 % of nominal voltage for 2 s</td>
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<tr>
<td>Voltage drop (A)</td>
<td>Less than 0.25 % of nominal voltage at rated current</td>
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<tr>
<td>System frequency tolerance (Hz)</td>
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</tr>
<tr>
<td>Voltage protection level (V)</td>
<td>120 V suppressor ≤350 V</td>
</tr>
<tr>
<td>System frequency tolerance (Hz)</td>
<td>208-V, 240-V suppressor ≤700 V</td>
</tr>
<tr>
<td>Voltage protection level (V)</td>
<td>480-V suppressor ≤1200 V</td>
</tr>
<tr>
<td>Voltage protection level (V)</td>
<td>Maximum peak overshoot voltage less than 250-V overvoltage protection level for voltage spike with 5 kV/µs or lower rate of rise</td>
</tr>
<tr>
<td>Response time (µs)</td>
<td>Less than 50 ns</td>
</tr>
<tr>
<td>Maximum leakage current (mA)</td>
<td>Less than 30-mA line-line or line-ground</td>
</tr>
</tbody>
</table>

8. **Performance Requirements**:

8.1 Surge protective devices that are series-connected (Types II, III, and IV) shall have supplementary overcurrent protection and overtemperature protection.

8.4 Supplementary overcurrent protection using fuses shall be readily replaceable while circuit breaker protected devices shall be replaceable.

8.4.1 Surge protective devices that are series-connected (Types II, III, and IV) shall have supplementary overcurrent protection and overtemperature protection.

8.4.2 Supplementary overcurrent protection using fuses shall be readily replaceable while circuit breaker protected devices shall be replaceable.

8.4.3 Supplementary overcurrent protection shall interrupt all phases of the source circuit plus the circuit neutral where applicable to assure suppressor isolation of the load.

8.4.4 Overtemperature protection shall sense suppressor enclosure or suppression device overtemperature condition and initiate opening of the voltage supply.

8.4.5 Suppressor supplementary protection shall provide a visual or audible indication or both of the opening of the protective device.
8. Enclosures

8.1 Unless specified differently by the purchaser, the suppressor shall be packaged in a safety grounded enclosure with foundation attachments that meets the requirements of UL 1449.

8.1.1 The enclosure shall be capable of confining any material that may be expelled during a catastrophic failure of any suppression device.

9. Receptacles

9.1 Receptacles provided as part of a suppressor shall have a current rating not more that the current rating of the suppressor and a voltage rating consistent with rating of the suppressor.

9.2 All receptacles shall be of the grounding type.

10. Design Tests

10.1 Insulation Withstand Test—The assembled insulating members of the surge suppressor shall withstand impulse and power-frequency voltages applied between each pair of line terminals and between each line terminal and the grounded case. Internal parts designed to conduct to discharge impulses shall be removed or rendered inoperative to permit these tests.

10.1.1 Impulse Insulation Withstand—A 1.2/50-µs impulse voltage wave, as defined by ANSI/IEEE Std 4, shall be applied between each set of line terminals and between each line terminal and ground. The magnitude of the impulse voltage shall be at least 1.2 times the sum of the voltage protection level (suppression rating) and the maximum peak overshoot voltage, but need not exceed 6 kV.

10.1.2 Power Frequency Insulation Withstand—An ac potential of the nominal system frequency shall be applied for a period of 1 min between each set of line terminals and between each line terminal and ground. The magnitude of the test voltage shall be 1000 V plus twice nominal system voltage. The same test voltage magnitude shall be applied for line-to-line and line-to-ground tests.

10.2 Power Frequency Withstand Test—Power frequency withstand tests shall be performed to demonstrate the ability of the surge suppressor to withstand sustained periods of operation at the maximum continuous operating voltage and periods of transient power frequency overvoltage without degradation. The power supply voltage, measured at the input terminals of the suppressor, shall be maintained as close as practicable to, but not less than, the specified test voltage. Three suppressors shall be connected across a power supply within the tolerances of the nominal frequency. The power supply shall have a short circuit capacity, measured at the suppressor input terminals, of at least 500 amps. For multi-phase suppressors, tests shall be performed for the assembled suppressor and power frequency voltage shall be applied to all phases.

10.2.1 Maximum Continuous Operating Voltage—The three test samples shall be placed in a controlled-temperature chamber with an ambient temperature of 85°C ± 5°C and the rated maximum continuous operating voltage shall be applied for a period of 1000 h. The suppressor leakage currents shall be measured at the beginning of the test (after the suppressor temperature has stabilized), and again after 1000 h. The leakage currents at the conclusion of the test shall be less than 30 mA and shall be less than 110 % of the initial leakage current for each sample.

10.2.2 Maximum Line-to-Ground Voltage—Rated maximum continuous operating voltage shall be applied to the three test suppressors between each line terminal and ground for a period of 1 h. A single-phase voltage source may be applied between all line terminals (in parallel) and ground for this test. Leakage current to ground shall not increase by more than 10 % at the conclusion of this test.

10.2.3 Temporary Overvoltage—The three test samples shall be exposed to ten cycles of temporary overvoltage. Each overvoltage cycle shall consist of 120 % of rated nominal voltage for a period of 2 s followed by the maximum continuous operating voltage for a period of 1 min. The leakage currents shall not exceed 30 Ma and the leakage current immediately following the 1-min period of the last cycle shall not exceed 110 % of the value obtained at the conclusion of the maximum continuous operating voltage test.

10.3 Impulse Voltage-Time Tests—The impulse voltaged-time tests demonstrate the suppressor’s ability to limit over-voltage in response to varying voltage spike rates of rise. Voltage impulses with fast (5 kV/µs) and slow (150 V/µs) rates of rise and of both polarities shall be applied between each set of input line terminals and between each line terminal and ground. Normal operating voltage need not be applied for these tests. The tests shall be performed on three samples, and the highest crest voltage recorded at the output terminals shall be less than the maximum peak voltage (voltage protection level plus peak overshoot). The response time shall also be less than 50 ns. For one-port type suppressors, input and output terminals are the same terminals. Where three-phase suppressors consist of three identical circuits, these tests need only be performed on one of the three circuits in each sample. If the suppressor discharge current exceeds 3000 amps, a resistance of up to 2 Ω may be added in series with the surge generator to limit the current after suppressor operation to 3000 amps.

10.3.1 Fast-Front Impulse Suppression Tests—A 1.2/50-µs voltage impulse wave having a prospective crest voltage of 6-kV (5-kV/µs rate of rise) shall be used for the fast-front test. Five impulses of each polarity shall be applied to each set of terminals and the maximum peak voltage and response time obtained line to line and line to ground shall be recorded.

10.3.2 Slow-Front Impulse Suppression Tests—Slowfront tests shall be performed using a voltage impulse with a prospective crest of 4.5 kV and a wavefront (time from zero to crest) of 30 to 60 µs (approximately 150-V/µs rate of rise). The time to half-crest value on the tail of the prospective waveform should be at least twice the wavefront time. Five impulses of each polarity shall be applied to each set of terminals and the maximum voltage and response time obtained line-to-line and line-to-ground shall be recorded.

10.4 Voltage Protection Level Tests—The purpose of this test is to determine the voltage protection provided by the suppressor when passing a surge current. The voltage protection level shall be measured at the output terminals of the suppressor using 8/20-µs current impulse waveforms of both polarities applied to the input terminals. Three new specimens
(not previously surged) shall be subjected to five 1500-amp impulses of each polarity, followed by one 3000-amp surge of both polarities, applied between each set of input terminals and between each input terminal and ground. The time interval between current impulses shall not exceed 120 s. In the event that the input voltage developed by the current impulse generator exceeds 6 kV after the initial suppressor overshoot, the current impulse magnitude may be limited to a value which produces a 6-kV input voltage. The maximum value of line-to-line and line-to-ground voltage protection level at each current level shall be recorded and shall be less than the rated maximum suppression voltage rating. The range of voltage protection level values obtained with the series of 1500-amp impulses across the same set of terminals on any one unit shall not vary by more than 10 %.

10.5 Duty Cycle Tests—The duty cycle test establishes the ability of the suppressor to interrupt follow current successfully and repeatedly. Duty cycle tests shall be performed using one of the three suppressors previously used in the power frequency withstand tests. The suppressor shall be connected across a power supply within the tolerances of the nominal frequency. The power supply voltage, measured at the input terminals of the suppressor, shall be maintained as close as practicable to, but not less than, the rated maximum continuous operating voltage. The power supply shall have a short circuit capacity, measured at the suppressor input terminals, of at least 500 amps.

10.5.1 A series of ten 8/20-µs current impulse waves with a crest value of 1500 A and constant polarity shall be applied line-to-line with a time interval between surges of 50 to 60 s. The first surge shall be timed to occur 30° after voltage, zero in the power-frequency half-cycle of the same polarity as the impulse. The second impulse will be timed to occur at 60°, and the timing will be increased an additional 30° for each subsequent surge. A second series of ten current impulses shall be applied line to ground, with the first surge of this series occurring within 2 min of the tenth line-to-line surge. The leakage current before the first impulse and immediately following the last impulse of each series of impulses and the suppression voltage rating during each surge shall be measured. The measured leakage currents shall be less than 30 mA. The leakage current following the last (tenth) impulse shall not have increased by more than 10 % of the value obtained before testing. The measured suppression voltage rating shall be less than the rated voltage protection level. The range of voltage suppression values obtained shall not vary by more than 10 %. If the voltage produced at the suppressor input terminals exceeds 6 kV, the current impulse magnitude may be limited to a value which produces a 6-kV input voltage. Where a three-phase unit consists of three identical circuits, or the peak overvoltages and clamping overvoltages determined by the previous tests are within 10 % for all three phases, only one line-to-line and one line-to-ground test need be performed.

10.6 Life Cycle Tests—Life cycle tests establish the ability of the suppressor to retain its voltage limiting function following exposure to a large number of impulses equivalent to the suppressor’s life expectancy.

10.6.1 Voltage Impulses—Upon successful completion of the duty cycle tests, the suppressor selected for duty cycle testing shall have a series of 1000 voltage impulses with a 1.2/50-µs waveshape and 6-kV magnitude applied between one phase and ground (or between the same two phases if no ground connection is used). Power frequency voltage need not be applied during these tests. If the suppressor discharge current for these tests exceeds 750 A, a resistance of up to 8 Ω may be added in series with the surge generator to limit the current after suppressor operation to 750 A. Surges shall be applied at 5-s intervals. Measurements of the maximum peak voltage (voltage protection level plus peak overshoot) shall be taken for the first ten surges and for the last ten surges. The average of the maximum peak voltage for the first ten surges and for the last ten surges shall not vary by more than 10 %.

10.6.2 Current Impulses—Following the 1000 voltage impulses, 1000 current impulses with an 8/20-µs waveshape and 750-A magnitude shall be applied to the same set of terminals as were used for the 1000 voltage surges. If the voltage developed at the input terminals exceeds 6 kV, the current impulse magnitude may be limited to a value which produces an input voltage of 6 kV. Nominal frequency voltage shall be applied to the suppressor immediately before and for at least 10 s following application of the current impulse. Current surges shall be applied at 5-s intervals. The value of voltage protection level and the leakage current through the suppressor 10 s following the impulse shall be measured for the first ten surges and the last ten surges. The average of these two parameters for the first ten and last ten measurements shall not vary by more than 10 %.

10.7 Load Current and Voltage Drop Tests—For two-port surge suppressors, tests of the ampacity and voltage drop shall be conducted on one sample. A reduced voltage source may be used for the performance of these tests. For multi-phase suppressors, tests shall be performed using the assembled suppressor and the specified magnitude of test current shall be conducted through all phases simultaneously.

10.7.1 Rated Current and Voltage Drop—A current not less than the rated current of the suppressor shall be passed through the device (from “input” to “output” terminals) for a period of 1 h. The maximum voltage between corresponding input and output terminals shall be measured with rated current flowing through the suppressor at the end of the 1-h test period and shall not exceed 0.25 % of the nominal system voltage. The temperature rise of the suppressor case and any internal current-carrying components shall not exceed 20°C.

10.7.2 Inrush Current—A current equal to ten times rated current shall be passed through the suppressor (from input to output terminals) for ten cycles without loss of continuity (including interruption of fuses or other protective devices), causing the suppressor to shunt or limit current, or elevating the temperature of the suppressor or any of its current-carrying components by more than 20°C. Maximum continuous operating voltage shall be applied immediately following the application of the inrush current, and the measured leakage current shall be less than 30 mA.
11. Conformance and Production Tests

11.1 Conformance testing of a random sample may be requested by the purchaser to verify that selected performance characteristics demonstrated in the design tests have been maintained in the production suppressors supplied. These tests would not normally be performed unless specifically required. Production tests are routine tests performed on production units (or samples thereof) to ensure that basic safety requirements are met.

11.1.1 Conformance Tests—Conformance tests shall be performed only as required by the purchaser on a representative sample, selected at random, of the units supplied by the manufacturer. When required, testing shall be performed on the assembled suppressor. Sample size, testing required, and pass/fail criteria must all be specified by the purchaser. The following sample sizes and tests are suggested for conformance testing.

11.1.1.1 Sample Size:

<table>
<thead>
<tr>
<th>No. Supplied</th>
<th>Test Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–20</td>
<td>1</td>
</tr>
<tr>
<td>21–50</td>
<td>3</td>
</tr>
<tr>
<td>51–100</td>
<td>5</td>
</tr>
<tr>
<td>101 and above</td>
<td>5 % of total</td>
</tr>
</tbody>
</table>

11.1.1.2 Power Frequency Test—Each sample would be placed in an ambient temperature of at least 25°C, and the rated maximum continuous operating voltage would be applied for a period of two hours. Five cycles of 120 % of nominal system voltage for a period of 2 s, followed by 1 min at the maximum continuous operating voltage would then be applied. The leakage current at the beginning and end of this test would be measured to verify that it is less than the 30 mA rated leakage. Leakage current at the conclusion of the test should be less than 110 % of the initial leakage to demonstrate no permanent degradation. Additionally, the maximum continuous operating voltage should be applied between the line terminals and the ground connection for a period of 5 min. The leakage current after 5 min should be less than 30 mA and should not have increased by more than 10 % from the initial value at the beginning of the power frequency test.

11.1.1.3 Impulse Voltage Test—A single 1.2/50-µs voltage impulse wave having a prospective crest voltage of 6 kV would be applied between each pair of input line terminals and between each input line terminal and ground for each sample. The maximum peak voltage and response time measured for each impulse should not exceed the rated maximum values.

11.1.1.4 Impulse Current Test—Each sample would be connected across a power supply with the nominal system voltage and frequency. A single 8/20-µs current impulse with a peak amplitude of 750 A would be applied between one pair of input line terminals and between one line terminal and ground (selected at random) for each sample. If the voltage at the input terminals of the suppressor exceeds 6 kV, the amplitude of the current impulse could be reduced to that value which produces an input voltage equal to, but not less than, 6 kV. The voltage protection level and response time at the output terminals and the suppressor leakage current would be measured and should be less than the rated maximum values.

11.1.2 Production Tests:

11.1.2.1 Insulation Withstand—Each suppressor shall withstand, without electrical breakdown, a voltage applied between the line terminals and the grounded case (including accessible dead metal parts). The voltage applied shall be 1000–V ac plus twice rated maximum continuous operating voltage for a period of 1 minute or 1200–V ac plus 2.4 times rated maximum continuous operating voltage for a period of 1 s. This test shall be performed when the suppressor is fully assembled. Alternatively, where the test voltage can damage solid-state components, the insulating structures of the suppressor may be tested before assembly of internal components, provided the test is representative of the completed suppressor and a random sample representing at least 1 % and at least three suppressors from the day’s completed production are tested with any internal components which may be damaged by the test disconnected.

11.1.3 Ground Continuity—Each suppressor provided with a means for grounding (for example, ground terminal or pin) shall be tested using an ohmmeter, battery/buzzer circuit tester, or similar device to determine continuity between the grounding connection and all accessible dead metal parts.

12. Certification Requirements

12.1 When specified in the purchase order or contract, a producer’s or supplier’s certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

13. Marking Requirements

13.1 The product shall be labeled or tagged to show:

13.1.1 Manufacturer’s name, model, serial number, and country of origin,

13.1.2 Product name,

13.1.3 Surge suppressor class and type,

13.1.4 Nominal rated voltage, current, frequency, and service,

13.1.5 Voltage protection level (in volts or kilovolts) for each protective mode.

14. Packaging Requirements

14.1 Product shall be packaged, boxed, crated, or wrapped to provide suitable protection during shipment and storage.

15. Keywords

15.1 ac power; circuits; surge current; surge suppression; surge suppressors; voltage transients
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are applicable to Navy procurements and shall apply only when specified by the purchaser in the contract or purchase order.

S1. Performance
S1.1 The surge suppressors shall meet the performance requirements of 7.1 except for voltage protection level at 480 V and minimum life which shall be in accordance with Table S1.1. In addition, the surge suppressors shall meet the performance requirements for minimum energy capability and minimum average power capability specified in Table S1.1.

S2. Life Cycle Test Requirements

<table>
<thead>
<tr>
<th>TABLE S1.1 Performance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Protection Level at 480 V</td>
</tr>
<tr>
<td>Minimum life</td>
</tr>
<tr>
<td>Minimum energy capability</td>
</tr>
<tr>
<td>Minimum average power capability</td>
</tr>
</tbody>
</table>

S2.1 The surge suppressors shall meet all the life cycle requirements specified in 10.6 with the following exceptions:
S2.1.1 Number of applied voltage impulses as described in 10.6.1 shall be 2500. Surges shall be applied at 12-s intervals.
S2.1.2 Number of applied current impulses as described in 10.6.2 shall be 2500. Surges shall be applied at 12-s intervals.

S3. Testing—The supplier is responsible for the performance of all testing and inspections. Except as otherwise specified, the supplier may use his own facilities or any commercial laboratory acceptable to the Government. The Government may reserve the right to perform any of the testing or inspections set forth in the specification requirements. This testing shall assure qualification on a one-time basis unless the manufacturer makes a significant change in materials or process.

APPENDIX

X1. ADDITIONAL INFORMATION ON DESIGN AND PERFORMANCE CONSIDERATIONS

X1.1 Shipboard Electrical Systems Environment:
X1.1.1 Transient voltage surge suppressors (TVSS) devices work better and can more effectively shunt damaging transient overvoltages and current pulses to electronic equipment, if system grounding is done properly and has good integrity. Therein lies the major problem with TVSS devices for shipboard use. Unlike industrial or commercial electrical systems which have an ac supply ground and an equipment ground, most shipboard electrical systems are “ungrounded.” Without a system ground (normally referred to as the neutral or common), then shipboard TVSS devices have protective modes that are limited to line-to-line and/or line-to-ground shunting of transients. Equipment (safety) grounds are achieved by proper mounting of equipment to the ship’s metal hull or structure or installation of grounding straps between the hull and isolated equipment. The effectiveness of shipboard TVSS will be highly dependent on the equipment grounding techniques.

X1.2 Single Component Versus Hybrid Transient Voltage Surge Suppressors:
X1.2.1 Activated by transient voltage and current, a TVSS component redirects or shunts a portion of the transient current through the device and away from the load. A number of TVSS components are available with each having distinct advantages and disadvantages. These components consist of two basic types of protector: clamps and crowbars. Clamps (metal-oxide varistors and silicon avalanche suppressors) simply limit, while crowbars (gas tubes and carbon-block arrestors) exhibit steep negative resistance characteristics that result in voltage protection levels well below their striking potential.

X1.2.2 Hybrid transient voltage surge suppressors are designed to take advantage of several different types of components thereby enhancing overall performance and reliability. Hybrids usually incorporate a high energy capable, primary suppression section and tighter clamping, lower energy section. A hybrid design appears simple, however the proper component selection by the manufacturer is critical so that they function together as a coordinated system. A properly designed hybrid TVSS will vastly outperform any single component suppressor.

X1.3 Series Versus Parallel Devices:
X1.3.1 Surge suppressor components are inherently parallel or “across the line” components making them insensitive to load currents. However, because any impedance between the surge suppressor component and the transient-carrying line greatly reduces their effectiveness, lead length is an important consideration. The ideal one-port (parallel or shunt-connected) surge suppressor configuration is one with leads as short as possible. Longer leads, especially those excessive in length, may entirely negate the capability of the surge suppressor. Unfortunately, most transient voltage suppressors are parallel in design and require long wire-up leads.

X1.3.2 Series-connected (two-port) TVSS systems require load current sensitivity because all load currents pass through them. However, leads may be minimized in two-port designs, thereby significantly enhancing performance. Additionally, most two-port surge suppressors offer hybrid designs that incorporate multiple components and a coupling inductor.
X1.4 Envelope Clamping Versus Sine Wave Clamping:

X1.4.1 There are two main types of surge suppressors, envelope or threshold clamping devices and sine-wave clamping devices. Envelope devices, which represents the majority of surge suppressors available today, use only solid-state protection components such as metal oxide varistors (MOVs) or silicon avalanche diodes and operate by limiting or clamping the voltage across their terminals. This voltage protection level depends on the transient current and waveshape and must be chosen high enough not to interfere with the normal operation of the protected line.

X1.4.2 Envelope clamping devices are very effective at preventing transient damage from occurring to simple devices such as motors or power supplies, where insulation breakdown from high voltage would occur. They are not effective at keeping transient energy from low-voltage supplies to sensitive electronics or microprocessors.

X1.4.3 Sine-wave clamping suppressors consist of complex hybrid filter/suppressor circuits that effectively attenuates high frequency transients at whatever phase angle it occurs. Sine-wave clamping devices create lower clamping levels ensuring that any residual transient which propagates through low voltage power supplies is too small to cause circuit damage or logic disruption at the circuit board level.

X1.4.4 Although more costly than single-component or envelope (threshold clamping) devices, the use of hybrid surge suppressors that offer high-energy suppression, high-speed suppression and a EMI/RFI filter be adopted. Such devices should be installed at power distribution panels and critical electronic equipment and computers.

X1.5 Networking Surge Suppressors:

X1.5.1 Networking surge suppressors gives superior performance and reduced costs over the application of single devices. Suppression networks are built by distribution of components at more that one point within as electrical system. Networks do more than just protect more loads at more places; they actually improve the performance of individual components, by taking advantage of the wire’s self-inductance between surge suppressors. Suppressor networks result in superior performance at a lower cost since the very best single point devices are no longer needed for effective protection.

X1.5.2 Networked surge suppressors reduce the amplitude of the transient step by step. The relationship of voltage protection level to current for suppression devices like MOVs is that the lower the current the lower the voltage protection level and, therefore the lower the residual voltage getting through to the load you are trying to protect. Transients act like waves in a transmission line. When the wave encounters a change of impedance (which occurs with the introduction of suppression component such as an MOV or silicon avalanche diode), then a portion of the transient is reflected (bounces back) in the opposite direction with an opposite polarity. That portion of energy which finds its way in between two suppression devices separated by (wire) inductance, bounces back and forth until it is dissipated or escapes into other forms of energy.

X1.6 Safety Features:

X1.6.1 There is a fire hazard with surge suppressors. Surge suppressors can and do catch fire. Suppressors used to protect sensitive electronic equipment in home, office, industry, Naval and marine against transient voltages on ac circuits have failed in service, some overheating seriously, melting and even catching on fire. The theoretical cause has been debated and fire hazard tests proposed, however the most practical solution is to include provisions in the equipment design to preclude the devices catching fire. Those recommended for consideration by the purchaser would include:

X1.6.1.1 Enclosure shall be metallic.

X1.6.1.2 Two-port devices shall include a circuit breaker that interrupts all phases (and neutral where applicable) of the supply circuit.

X1.6.1.3 Thermal protection of TVSS shall interrupt supply circuit for overtemperature condition.

X1.6.1.4 Fail open circuit that automatically shuts off power to connected equipment in the event of a suppression component failure and protects equipment from being exposed to unfiltered “raw” power.

X1.6.2 Thermal failure modes of gapless, varistor-based surge suppressors is considered significantly more likely than failure to a surge suppressor during a large, single energy transient. Thermal failure involves thermal runaway from one of three sets of circumstances:

X1.6.2.1 Following a large transient that elevated the temperature of MOV beyond point of recoverable thermal equilibrium.

X1.6.2.2 During an extended temporary overvoltage (sometimes referred to as a “voltage swell”).

X1.6.2.3 At the end of the life of a device previously exposed to repetitive temporary overvoltages or surges, when the rated number and magnitude of pulses for that device has been exceeded and the standby current has slowly increased to a point where thermal runaway develops.

X1.6.3 Surge suppressors, as recommended in this standard, should include a thermal cutoff device (in addition to an overcurrent protective device) that will sense the varistor temperature and interrupt the supply source during the initial part of the thermal runaway. In reality, the thermal failure modes of X1.6.2.1 and X1.6.2.2 may happen too fast for a cut-off device to act before terminal thermal runaway. The failure mode defined in X1.6.2.3 is the most preventable by a closely coupled cutoff device.
Standard Specification for Angle Style, Pressure Relief Valves for Steam, Gas, and Liquid Services

This standard is issued under the fixed designation F 1508; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers spring-loaded, angle style, pressure relief valves for steam, gas, and liquid system applications (excluding boiler safety and hydraulic system relief valves).

2. Referenced Documents

2.1 ASTM Standards: 2
A 105/A 105M Specification for Carbon Steel Forgings for Piping Applications
A 125 Specification for Steel Springs, Helical, Heat-Treated
A 182 Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 193 Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
A 227/A 227M Specification for Steel Wire, Cold-Drawn for Mechanical Springs
A 229/A 229M Specification for Steel Wire, Oil-Tempered for Mechanical Springs
A 231/A 231M Specification for Chromium-Vanadium Alloy Steel Spring Wire
A 276 Specification for Stainless Steel Bars and Shapes
A 313/A 313M Specification for Stainless Steel Spring Wire

A 351/A 351M Specification for Castings, Austenitic, Austenitic FERRITIC (Duplex), for Pressure-Containing Parts
A 479/A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
A 494/A 494M Specification for Castings, Nickel and Nickel Alloy
A 689 Specification for Carbon and Alloy Steel Bars for Springs
B 21/B 21M Specification for Naval Brass Rod, Bar, and Shapes
B 61 Specification for Steam or Valve Bronze Castings
B 62 Specification for Composition Bronze or Ounce Metal Castings
B 148 Specification for Aluminum-Bronze Sand Castings
B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire
B 637 Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service
D 5204 Classification System for Polyamide Imide (PAI) Molding and Extrusion Materials
F 467 Specification for Nonferrous Nuts for General Use
F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
2.2 ANSI Standards: 3
ANSI B.1 Unified Screw Threads
ANSI B16.5 Pipe Flanges and Flanged Fittings
ANSI B16.34 Valves—Flanged, Threaded, and Welding End
2.3 ASME Standard: 4
Boiler and Pressure Vessel Code
2.4 API Standards: 5
API Standard 526 Flanged Steel Safety-Relief Valves
API Standard RP 520, Part 1 Recommended Practice for the Design and Installation of Pressure-Relieving Systems in Refineries

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.


4 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

5 Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.
2.5 **Federal Specifications:**

QQ-N-281 Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections

QQ-N-286 Nickel-Copper-Aluminum Alloy, Wrought (UNS N05500)

2.6 **Military Standards and Specifications:**

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)

MIL-STD-1330 Cleaning and Testing of Shipboard Oxygen, Nitrogen and Hydrogen Gas Piping Systems

MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver Brazing, General Specification for

MIL-F-20042 Flanges, Pipe and Bulkhead, Bronze (Silver Brazing)

MIL-P-46122 Plastic Molding Material and Plastic Extrusion Material, Polyvinylidene Fluoride Polymer and Copolymer

MIL-R-17131 Rods, Welding, Surfacing

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for MS 16142 Boss, Gasket-Seal Straight Thread Tube Fitting, Standard Dimensions for

MS 51840 Plug, Machine Thread, O-ring

2.7 **Naval Sea Systems Command (NAVSEA):**

*Drawings:*

803-1385884 Unions, Fittings and Adapters, Butt and Socket Welding, 6000 PSI, WOG IPS

803-1385943 Unions, Silver Brazing, 3000 PSI, WOG IPS, for UT Inspection

803-1385946 Unions, Bronze Silver Brazing, WOG, for UT Inspection

### 3. Terminology

#### 3.1 Definitions:

3.1.1 **accumulation**—the increase in static pressure above the set pressure during discharge through the valve, when the valve passes the rated flow. Accumulation is expressed in pound-force per square inch or as a percent of the set pressure.

3.1.2 **accumulation pressure**—the set pressure plus the accumulation. Accumulation pressure is expressed in pound-force per square inch gage.

3.1.3 **blowdown**—the difference between the set pressure and the reseating pressure. Blowdown is expressed in pound-force per square inch or a percent of the set pressure. The accumulation and blowdown establish the operating band of the pressure relief valve at a particular set pressure.

3.1.4 **blowdown pressure**—the set pressure minus the blowdown. Blowdown pressure is expressed in pound-force per square inch gage.

3.1.5 **built-up backpressure**—the static discharge pressure at the outlet of a pressure relief valve caused by the pressure drop in the discharge piping while the valve is discharging.

3.1.6 **gagging device**—a device, normally a screw (also called test gag), used to prevent the pressure relief valve from opening during a hydrostatic pressure test of the equipment on which it is installed.

3.1.7 **inlet piping**—when used in this specification, refers to all piping and fittings between the source and the inlet connection to the pressure relief valve.

3.1.8 **instability (chatter, flutter)**—an unstable operation of the pressure relief valve characterized by rapid seating and unseating of the disk during discharge. This hammering of the disk on the seat can cause high loading forces, which can lead to damage and rapid failure of the seating and sliding surfaces.

3.1.9 **maximum system operating pressure**—the highest pressure that can exist in a system, vessel, or component under normal (noncasualty) operating conditions. This is a normal (noncasualty) pressure that the pressure relief valve is not intended to protect against. This pressure can be the result of influences such as pump or compressor shutoff pressure, pressure regulating valve lockup (no flow) pressure, and so forth.

3.1.10 **opening pressure**—the value of increasing inlet static pressure of a pressure relief valve at which there is a measurable lift, or at which the discharge becomes continuous by seeing, feeling, or hearing.

3.1.11 **outlet piping (or discharge piping)**—when used in this specification, refers to all piping and fittings between the pressure relief valve outlet connection and the main, tank, or atmosphere to which the pressure relief valve relieves.

3.1.12 **popping pressure**—the value of increasing inlet static pressure at which the disk moves in the opening direction at a faster rate as compared with the corresponding movement at higher or lower pressures. It generally applies to valves with compressible fluid service such as steam, gas, and so forth.

3.1.13 **pressure relief valve**—an automatic pressure relieving device actuated by the static pressure upstream of the valve and characterized by either rapid opening (pop action for gas, vapor, or steam) or gradual opening (for liquids).

3.1.14 **primary and secondary pressure zones of pressure relief valve**—primary pressure zone refers to all portions of the pressure-containing envelope subject to inlet pressure; secondary pressure zone refers to all portions of the pressure-containing envelope subject to outlet or discharge pressure (includes spring housing of nonvented valves).

3.1.15 **relieving capacity (also called flow capacity)**—the pressure relief valve is defined as the quantity of pressure medium relieving through the pressure relief valve at the accumulation pressure, such as pound per hour of steam, gallon per minute of water at 70°F, or SCFM (standard cubic feet per minute at 60°F and 14.7 psia) of air, as applicable.

3.1.16 **set pressure**—the value of increasing inlet static pressure at which a pressure relief valve displays one of the operational characteristics as defined under opening pressure, or start-to-lease pressure. Set pressure is expressed in pound-force per square inch gage.

3.1.17 **set pressure range**—the range over which the set pressure can be adjusted with the installed spring.

3.1.18 **set pressure tolerance**—the permissible plus or minus deviation from the specified set pressure. Set pressure

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*Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.*
tolerance is expressed in pound-force per square inch or as a percent of the set pressure.

3.1.19 source—when used in this specification, refers to the pressure container being protected from overpressure by the pressure relief valve, for example, piping main, pressure vessel or tank, casing, and so forth.

3.1.20 start-to-leak pressure—the value of increasing inlet static pressure at which the first bubble occurs when a pressure relief valve for compressible fluid service of the resilient disk design is tested by means of air under a specified water seal on the outlet.

3.1.21 superimposed backpressure—the static pressure on the discharge side of a pressure relief valve prior to the opening of the pressure relief valve. This pressure exists where the pressure relief valve discharges into a common pipeline shared with other pressure sources such as pressure relief valves, or into a pressurized or closed system. This pressure may have the effect of changing the set pressure of the pressure relief valve.

3.1.22 top-guided valve—this type of valve has all the guiding, rubbing, or contacting surfaces on the discharge side of the seat.

4. Classification

4.1 Pressure relief valves shall be of the following types and material grades:

4.1.1 Type I—For Steam Service:

4.1.1.1 Grade A—Alloy steel construction (for steam service temperatures up to 1000°F) (see Table 8).

4.1.1.2 Grade B—Carbon steel construction (for steam service temperatures up to 775°F) (see Table 8).

4.1.2 Type II—For Air, Gas Service:

4.1.2.1 Grade C—Bronze or stainless steel construction (for air, gas service excluding oxygen) (see Table 9).

4.1.2.2 Grade D—Ni-Cu alloy construction (for oxygen) (see Table 9).

4.1.3 Type III—For Liquid Service (except hydraulic oil):

4.1.3.1 Grade E—Ferrous construction (for noncorrosive liquids, such as fuel oil, water, steam condensate, and so forth) (see Table 9).

4.1.3.2 Grade F—Nonferrous construction (for corrosive liquids, such as seawater, and so forth) (see Table 9).

5. Ordering Information

5.1 Ordering documentation for valves under this specification shall include the following information, as required, to describe the equipment adequately.

5.1.1 ASTM designation and year of issue.

5.1.2 Valve specification code (see 6.2).

5.1.3 Quantity of valves.

5.1.4 Maximum inlet temperature.

5.1.5 Set pressure.

5.1.6 Required relieving capacity (flow) at the accumulation pressure.

5.1.7 Installation limitations data, if different than specified in 7.9.

5.1.8 Blowdown limits, if different than specified in 7.7.

5.1.9 Envelope dimensions, if not covered in Table 13 and Table 14.

5.1.10 Supplementary requirements, if any (see S1 through S5).

6. Valve Coding and Construction

6.1 Valves shall incorporate the design features specified in 6.2 and 6.3.

6.2 Valve Specification Coding—Basic valve design features shall be specified and recorded using the following valve coding system. The valve specification code contains nine fields of information, which describe the construction features of the valve. Each of these nine fields is further assigned their respective codes in accordance with Tables 1-7.

6.3 Construction—Valve construction shall be in accordance with the requirements specified in 6.3.1-6.3.19.

6.3.1 The materials of construction for various valve components are detailed in Table 8 for Type I valves and Table 9 for Types II and III valves.

6.3.2 General Requirements—The valve shall be self-contained, single-seated, and spring-loaded where the inlet pressure is directly sensed under the spring-loaded disk. The valve shall incorporate only a single inlet and a single outlet connection.

6.3.3 Pressure-Temperature Ratings—The pressure-temperature ratings of a pressure relief valve consist of ratings for the primary and secondary pressure zones.

6.3.3.1 Pressure-Temperature Rating of the Primary Pressure Zone—This shall correspond to the rating of the inlet end connection, and is given in Table 10.

6.3.3.2 Pressure-Temperature Rating of the Secondary Pressure Zone—The secondary pressure zone shall withstand the higher of the following:

1. 150% of maximum backpressure buildup specified in 7.9.

2. 600 psig (for Type II, Grade C and Type III, Grade F valves only).

3. ANSI B16.34, Class 150 pressure rating (for Type I, Grades A and B and Type III, Grade E valves only).

<table>
<thead>
<tr>
<th>TABLE 1 Valve Type and Material Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve Type Classification</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>V</td>
</tr>
<tr>
<td>VI</td>
</tr>
<tr>
<td>As specified</td>
</tr>
</tbody>
</table>
TABLE 2 Codes for Valve Inlet/Outlet Pipe Size

| 0.25 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.38 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.50 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.75 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.25 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.50 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.50 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.50 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.0 | | | | | | | | | | | | | | | | | | | | | | | | | |

TABLE 3 End Connection Codes for Valve Inlet and Outlet Ports

**Note 1**—Unless otherwise specified in the purchase order (Code W), all ANSI flanges shall have raised faces.

**Note 2**—Unless otherwise specified in the purchased order (Code W), all Navy flanges shall be plain and without preinserted rings.

6.3.4 Body Construction—The valve shall be of the angle-body design. It shall be constructed so that the seat will not become distorted relative to the disk, and valve operation is not adversely affected by internal pressure and temperature.

6.3.5 Bonnet Construction (Spring Housing):

6.3.5.1 For Type I valves, the bonnet shall be attached to the body with bolted flanges. Type I, Grade A valves must have exposed spring bonnets—the discharge flow released through the open bonnet shall be minimal. For Type II and Type III valves, the bonnet shall be attached to the body with bolted flanges, or a threaded union connection.

6.3.5.2 For pressure-tight (nonvented) bonnet construction valves (for air/gas and liquid applications), there shall be no discharge of pressure medium into the atmosphere from the bonnet or from the body-to-bonnet joint.

6.3.5.3 Vented-bonnet construction valves shall incorporate a threaded vent hole in the bonnet for the discharge of pressure medium into the atmosphere. The discharge flow released through the vent hole shall be minimal. The vent hole shall be capable of attaching a pressure-tight MS straight-threaded tube fitting to divert the pressure relief to a distant location. The nominal tube fitting size shall be in accordance with Table 11.

The vent hole shall be in accordance with MS 16142. Valves shall be furnished with a vent plug in accordance with MS 51840 to keep the dirt away and to allow hydro testing. A warning tag instructing the mandatory removal of the vent plug after valve installation must also be attached to the valve vent plug.

6.3.5.4 There shall be one bonnet for each valve body of a particular nominal inlet size and pressure-temperature rating. It shall be capable of housing any of the springs required to span the applicable set pressure ranges.

6.3.6 Internal Trim:

6.3.6.1 For Type I valves, valves shall be provided with a threaded seat ring, which shall be welded or nickel-brazed circumferentially to the body. The valve body shall have sufficient metal at the seat section to permit installation of a separate seat ring, if required as a service repair. When the seat ring is a part of the inlet flange raised face, such as in full nozzle valves, no welding or brazing is required.

6.3.6.2 For Type II and III valves, the valve shall have a replaceable seat ring. The seat ring shall be either thread-in or retained by a cage construction and shall be easily replaceable, using hand tools, after extended service.

6.3.6.3 The valve disk to valve seat sealing must be metal to metal for Type I valves and metal to nonmetal for Type II and Type III valves.

6.3.6.4 The disk or the disk holder assembly shall be top-guided. Bottom-guided valves (also known as wing-guided valves), or other construction valves where all or part of the guiding surfaces are under the disk, are not permitted. Guiding surfaces (bushings and posts) shall have the proper hardness, finish, concentricity, parallelism, clearances, length, and rigidity to prevent binding or seizing and to ensure proper seating under all operating conditions. These alignment requirements shall be maintained with interchangeable parts and under any tolerance stackup.

6.3.7 Interchangeability—In no case shall the parts be physically interchangeable in a valve unless such parts are also interchangeable with regard to function, performance, and strength. Where machining is required after installation of a seat ring or guide to maintain critical concentricity or alignment dimensions, detailed instructions must be provided with each repair part.

6.3.8 Spring—The spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and height measured 10 min after the spring has been compressed solid.
four times at room temperature) shall not exceed 0.5 % of the free height. Spring ends shall be squared and ground.

6.3.9 Threads—Threads shall conform to ANSI B1.1. Provisions shall be incorporated to prevent the accidental loosening of threaded parts. Pipe threads and lock-washers shall not be used.

6.3.10 Bearing Surfaces—Nut- and bolt-bearing surfaces and their respective mating surfaces on the valves shall be machine finished.

6.3.11 Stem Packing—A stuffing box, O-rings, or any other nonmetallic materials shall not be permitted on the stem/disk guiding surfaces.

6.3.12 Hand-Lifting Device—When specified (see 6.2), valves shall be provided with a hand-lifting device so that they may be operated by hand for testing purposes with an inlet pressure of 75 % of the set pressure. Type I and Type III valves must be furnished with a hand-lifting device. The necessary lever or tool shall be furnished as part of the valve. For valves requiring pressure-tight (nonvented) bonnets, a stuffing box or a seal on the shaft of the hand-lifting device which will have no effect on the valve set pressure and the valve lift, shall be required.

6.3.13 Gagging Device—When specified for system test purposes (see 6.2), a gagging device shall be supplied with the valve. Valves shall be constructed to be gagged without alteration of the set point. The gagging screw shall be provided with a knurled or wing nut-type head to discourage the use of

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**TABLE 4 Bonnet Construction Codes**

<table>
<thead>
<tr>
<th>Type of Bonnet Construction</th>
<th>Code for Type I Valve</th>
<th>Code for Type II Valve</th>
<th>Code for Type III Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade A</td>
<td>Grade B</td>
<td>Grade C</td>
<td>Grade D</td>
</tr>
<tr>
<td>Ventilated bonnet</td>
<td>not applicable</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Pressure-tight bonnet</td>
<td>not applicable</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Open bonnet (exposed spring)</td>
<td>C</td>
<td>not applicable</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

**TABLE 5 Hand-Lifting Device Codes**

<table>
<thead>
<tr>
<th>Is Hand-Lifting Device Required With the Valve?</th>
<th>Code for Type I Valves</th>
<th>Code for Type II Valves</th>
<th>Code for Type III Valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>not applicable</td>
<td>2</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

**TABLE 6 Gagging Device Codes**

<table>
<thead>
<tr>
<th>Is Gagging Device Required With the Valve?</th>
<th>Code for Type I Valves</th>
<th>Code for Type II Valves</th>
<th>Code for Type III Valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**TABLE 7 Valve Envelope Dimensions Code**

<table>
<thead>
<tr>
<th>Requirement to Meet Listed Envelope Dimensions</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>The valve meets the envelope dimensions listed in Table 12 and Table 13.</td>
<td>1</td>
</tr>
<tr>
<td>The valve does not meet the envelope dimensions listed in Table 12 and Table 13.</td>
<td>2</td>
</tr>
</tbody>
</table>

**TABLE 8 Materials of Construction for Type I Valves**

<table>
<thead>
<tr>
<th>Name of Part</th>
<th>Grade A</th>
<th>Grade B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body, bonnet, and yoke</td>
<td>Specification A 182 Grade F11, F22</td>
<td>Specification A 105/ A 105M</td>
</tr>
<tr>
<td></td>
<td>Specification A 217/ A 217M Grade WC6, WC9</td>
<td></td>
</tr>
<tr>
<td>Metallic disk and seat ring</td>
<td>Specification A 25 or Stellite (wrought Stellite 6B, cast)</td>
<td>Specifications A 276, A 479/A 479M Types 302, 304, 316, 410, 430</td>
</tr>
<tr>
<td></td>
<td>Specification A 25 or Stellite not less than ( \frac{3}{16} ) in. thick. Where inlays are used, welding rod shall be in accordance with Type MIL-R-CoCr-A of MIL-R-17131 and base materials shall be one of the following: Specification A 351/A 351M Grade CF3, CF3M, CF8, CF8M</td>
<td>Specifications A 276, A 479/A 479M Types 302, 304, 316, 410, 430</td>
</tr>
<tr>
<td>Stem</td>
<td>Specifications A 276, A 479/A 479M Types 302, 304, 316, 410, 430</td>
<td>Specifications A 276, A 479/A 479M Types 302, 304, 316, 410, 430</td>
</tr>
<tr>
<td>Springs</td>
<td>Specification B 637 (Inconel X750)</td>
<td>Specifications A 125/ Specification A 227/ A 227MA</td>
</tr>
<tr>
<td>Body bolts and nuts</td>
<td>Specification A 193 Grade B16</td>
<td>Specification A 193 Grade B7, B16 Specification A 194/A 194M Grade 2H, 4</td>
</tr>
</tbody>
</table>

\^ Electroless nickel plated (ENP) or zinc plated.
wrenches when gagging the valve. The gagging device shall be constructed to minimize the possibility of overlooking its removal after test and shall include a tag or other warning to this effect. The gagging device shall be designed to prevent the installation of a valve cap over the gagging device.

TABLE 9 Materials of Construction for Types II and III Valves

<table>
<thead>
<tr>
<th>Name of Part</th>
<th>Type II, Grade C</th>
<th>Type II, Grade D</th>
<th>Type III, Grade E</th>
<th>Type III, Grade F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade WCB</td>
<td>Grade WCB</td>
<td>Grade CF3, CF3M, CF8, CF8M</td>
<td>Grade WCB</td>
</tr>
<tr>
<td>Metallic disk and seat ring</td>
<td>Specifications B 61, B 62</td>
<td>Specifications B 61, B 62</td>
<td>Specifications A 494/A 494M</td>
<td>Specifications A 494/A 494M</td>
</tr>
<tr>
<td></td>
<td>Specifications A 494/A 494M</td>
<td>Specifications A 494/A 494M</td>
<td>Specifications A 494/A 494M</td>
<td>Specifications A 494/A 494M</td>
</tr>
<tr>
<td></td>
<td>Grade CF3, CF3M, CF8, CF8M</td>
<td>Grade CF3, CF3M, CF8, CF8M</td>
<td>Grade CF3, CF3M, CF8, CF8M</td>
<td>Grade CF3, CF3M, CF8, CF8M</td>
</tr>
<tr>
<td></td>
<td>Specifications B 21/B 21M</td>
<td>Specifications B 21/B 21M</td>
<td>Specifications B 21/B 21M</td>
<td>Specifications B 21/B 21M</td>
</tr>
<tr>
<td>Springs</td>
<td>Specification A 125A</td>
<td>Specification A 125A</td>
<td>Specification A 125A</td>
<td>Specification A 125A</td>
</tr>
<tr>
<td></td>
<td>Specification A 229/A 229M</td>
<td>Specification A 229/A 229M</td>
<td>Specification A 229/A 229M</td>
<td>Specification A 229/A 229M</td>
</tr>
<tr>
<td></td>
<td>Specifications A 276, A 313/ A 313M</td>
<td>Specifications A 276, A 313/ A 313M</td>
<td>Specifications A 276, A 313/ A 313M</td>
<td>Specifications A 276, A 313/ A 313M</td>
</tr>
<tr>
<td></td>
<td>Specifications F 467, F 468</td>
<td>Specifications F 467, F 468</td>
<td>Specifications A 194/A 194M</td>
<td>Specifications A 194/A 194M</td>
</tr>
<tr>
<td>Diaphragm, gasket, and so forth</td>
<td>TFE or reinforced TFE, nitrile (Buna-N), fluorocarbon-rubber (viton)</td>
<td>TFE or reinforced TFE, nitrile (Buna-N), fluorocarbon-rubber (viton)</td>
<td>TFE or reinforced TFE, nitrile (Buna-N), fluorocarbon-rubber (viton)</td>
<td>TFE or reinforced TFE, nitrile (Buna-N), fluorocarbon-rubber (viton)</td>
</tr>
<tr>
<td>Nonmetallic disk insert</td>
<td>TFE or reinforced TFE, Plastic in accordance with MIL-P-46122 with Classification System D 5204</td>
<td>TFE or reinforced TFE, Plastic in accordance with MIL-P-46122 with Classification System D 5204</td>
<td>TFE or reinforced TFE, Plastic in accordance with MIL-P-46122 with Classification System D 5204</td>
<td>TFE or reinforced TFE, Plastic in accordance with MIL-P-46122 with Classification System D 5204</td>
</tr>
</tbody>
</table>

Electroless nickel plated (ENP).

TABLE 10 Pressure Temperature Ratings of Valve

<table>
<thead>
<tr>
<th>End Connection Code (See Table 3)</th>
<th>Type of End Connection</th>
<th>Pressure-Temperature Rating (see 6.3.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A thru E</td>
<td>ANSI Flanged</td>
<td>Refer to ANSI B16.5</td>
</tr>
<tr>
<td>F</td>
<td>SBU, MIL-F-1183 (400 psi)</td>
<td>Nominal Pressure, psi, Design Pressure, psig, Design Temperature, °F, Shell Test Pressure, psig</td>
</tr>
<tr>
<td>G</td>
<td>Union-End, Drawing 803-1385946 (1500 psi)</td>
<td>400, 480, 165, 800</td>
</tr>
<tr>
<td>H</td>
<td>Union-End, Drawing 803-1385943 (3000 psi)</td>
<td>1500, 1800, 165, 2250</td>
</tr>
<tr>
<td>I</td>
<td>Union-End, Drawing 803-1385884 (6000 psi)</td>
<td>3000, 3600, 165, 4500</td>
</tr>
<tr>
<td>K</td>
<td>6-in. long nipple welded (400 psi)</td>
<td>6000, 7200, 165, 9000</td>
</tr>
<tr>
<td>L</td>
<td>6-in. long nipple welded (1500 psi)</td>
<td>as specified</td>
</tr>
<tr>
<td>M</td>
<td>6-in. long nipple welded (3000 psi)</td>
<td>as specified</td>
</tr>
<tr>
<td>N</td>
<td>6-in. long nipple welded (6000 psi)</td>
<td>as specified</td>
</tr>
<tr>
<td>P, R, T</td>
<td>Navy flanged, MIL-F-20042</td>
<td>refer to MIL-F-20042</td>
</tr>
<tr>
<td>W</td>
<td>as specified</td>
<td>as specified</td>
</tr>
</tbody>
</table>
6.3.14 Accessibility—Valves shall permit adjustment and repair without removal from the line.

6.3.15 Valve Adjustment:

6.3.15.1 Means shall be provided for adjusting the set pressure setting with the valve under pressure. The adjusting screw shall have right-hand threads so that clockwise rotation increases the set pressure. The adjusting device shall be provided with a locknut and cap, or other suitable means, to prevent accidental change of adjustment.

6.3.15.2 Valves shall have adjustable blowdown using blowdown ring(s). Positive means shall be used to lock the adjusting ring(s) in place by use of adjustable ring pins(s). The pin(s) shall be installed through the penetration hole in the lower valve body.

6.3.16 Valve Envelope Dimensions—Unless otherwise specified in the ordering data, valves must meet the overall envelope dimensions shown in Table 12 for Type I valves and Table 13 for Types II and III valves.

6.3.17 Cleaning—Type II, Grade D valve parts (for oxygen service) shall be cleaned in accordance with MIL-STD-1330 and maintained oxygen clean.

6.3.18 Sealing—Means shall be provided in the design of all valves for sealing all external adjustments such as set pressure. Seals shall be installed by the manufacturer or assembler at the time of initial shipment and after field adjustment or repair of the valves by either the manufacturer, his authorized representative repairer, or the user. Seals shall be installed in such a manner as to prevent changing the adjustment without breaking the seal and, in addition, shall serve as a means of identifying the manufacturer, assembler, repairer, or user making the adjustment.

6.3.19 Asbestos material is not permitted in the valve construction.

7. Performance Requirements

7.1 All valves shall meet the requirements of 7.2-7.10.

7.2 Range of Set Pressure Adjustment—For Type I and Type III valves, the set pressure shall be adjustable over a range of at least ±10% of the specified set pressure, for set pressures up to 250 psig; and when the specified set pressure exceeds 250 psig, this range shall be ±5%. For Type II valves, the set pressure shall be adjustable over the set pressure range specified in Table 14. If required, more than one spring may be used to accomplish this.

### TABLE 11 Nominal Tube Sizes (Inches) for Vented-Bonnet Valves

<table>
<thead>
<tr>
<th>Valve Inlet Size</th>
<th>Nominal Tube Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.250</td>
<td>0.375</td>
</tr>
<tr>
<td>0.375</td>
<td>0.375</td>
</tr>
<tr>
<td>0.500</td>
<td>0.375</td>
</tr>
<tr>
<td>0.750</td>
<td>0.375</td>
</tr>
<tr>
<td>1.000</td>
<td>0.500</td>
</tr>
<tr>
<td>1.250</td>
<td>0.500</td>
</tr>
<tr>
<td>1.500</td>
<td>0.625</td>
</tr>
<tr>
<td>2.000</td>
<td>0.625</td>
</tr>
<tr>
<td>2.500</td>
<td>0.750</td>
</tr>
<tr>
<td>3.000</td>
<td>0.750</td>
</tr>
<tr>
<td>4.000</td>
<td>1.000</td>
</tr>
<tr>
<td>5.000</td>
<td>1.000</td>
</tr>
<tr>
<td>6.000</td>
<td>1.250</td>
</tr>
<tr>
<td>8.000</td>
<td>1.250</td>
</tr>
</tbody>
</table>

7.3 Performance Testing:

7.3.1 Type I and Type III valves of non-automotive classification shall be tested to the requirements of 7.3.2.

7.3.2 Type II valves of non-automotive classification shall be tested to the requirements of 7.3.3 and 7.3.4, if applicable.

### TABLE 12 Valve Envelope Dimensions (Inches) for Type I Valves (See Fig. 1)

**Note 1**—Variations for A and B dimensions are ±0.06 in. C is the maximum dimension shown.

**Note 2**—Dimensions not shown in the table shall be in accordance with API 526. If dimensions are not shown in Table 12, or are not listed in API 526, they should be agreed upon between the buyer and the valve supplier.

<table>
<thead>
<tr>
<th>Type of Inlet × Outlet End Connections</th>
<th>ANSI 300 × ANSI 150</th>
<th>ANSI 600 × ANSI 150</th>
</tr>
</thead>
<tbody>
<tr>
<td>A B C A B C A B C A B C A B C A B C A B C</td>
<td>0.25 0.50 0.75 1.00 1.25 1.50 2.00 3.00 4.00 5.00 6.00 8.00 10.0 0.25 0.50 0.75 1.00 1.25 1.50 2.00 3.00 4.00 5.00 6.00 8.00 10.0</td>
<td></td>
</tr>
</tbody>
</table>
7.3 Operation—Valves shall operate without instability throughout their full range of capacity. Types I and II valves shall open with a clear, sharp pop. Valve closure shall be clear and sharp when the inlet pressure is reduced to the blowdown pressure. Type III valves shall open/close gradually, without instability, in response to the increase/decrease in pressure over the opening pressure.

7.4 Hydrostatic Shell Test Pressure—The valve shall show no signs of external leakage, permanent deformation, or structural failure when subjected to the hydrostatic shell test pressure specified in 8.2.

7.5 Set Pressure Tolerance—For all types of valves, the set pressure tolerance, plus or minus, shall not exceed the following: 2 psi for set pressures up to 70 psig, 3 % for set pressures over 70 psig up to 300 psig, 10 psi for set pressures over 300 psig up to 1000 psig, and 2 % for set pressures over 1000 psig.

7.6 Accumulation—Valves shall be sized to pass the specified flow (see 5.1.6) without permitting the inlet pressure (source static pressure) to rise beyond the accumulation pressure. The accumulation (overpressure) shall not exceed 10 % of set pressure, or 3 psi, whichever is greater. The valve shall show no signs of instability.

7.7 Blowdown Limits—Unless otherwise specified in the ordering data (see 5.1.8), valves shall operate satisfactorily with the following blowdown pressure setting:

7.7.1 For Type I and Type II valves, the maximum blowdown limit shall be 3 psi or 7 % of the set pressure, whichever is greater.

7.7.2 For Type III valves, the maximum blowdown limit shall not exceed 15 % of the set pressure or 3 psi, whichever is greater.

7.8 Seat Tightness—With an inlet pressure at or above the minimum allowable blowdown pressure setting, the valve shall seat tightly. No through seat leakage under this condition shall be allowed (see Table 15).

TABLE 13 Valve Envelope Dimensions (Inches) for Type II, Grade C, and Type III Valves (see Fig. 1) (Without Tailpieces and Nuts)

NOTE 1—Variations for A and B dimensions are ±0.06 in. C is the maximum dimension shown.

NOTE 2—Dimensions do not include length of nut or tailpiece.

NOTE 3—Dimensions not shown in the table should be agreed upon between the buyer and the valve supplier.

7.7.1 For Type I and Type II valves, the maximum blowdown limit shall be 3 psi or 7 % of the set pressure, whichever is greater.

7.7.2 For Type III valves, the maximum blowdown limit shall not exceed 15 % of the set pressure or 3 psi, whichever is greater.

7.8 Seat Tightness—With an inlet pressure at or above the minimum allowable blowdown pressure setting, the valve shall seat tightly. No through seat leakage under this condition shall be allowed (see Table 15).

TABLE 14 Range of Set Pressure Adjustment for Type II Valves

<table>
<thead>
<tr>
<th>Nominal Pressure Rating, lb/in.² gage</th>
<th>Minimum Required Set Pressure, lb/in.² gage</th>
<th>Maximum Required Set Pressure, lb/in.² gage</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>1500</td>
<td>460</td>
<td>1725</td>
</tr>
<tr>
<td>3000</td>
<td>1725</td>
<td>3450</td>
</tr>
<tr>
<td>6000</td>
<td>3450</td>
<td>6875</td>
</tr>
</tbody>
</table>

7.3 Operation—Valves shall operate without instability throughout their full range of capacity. Types I and II valves shall open with a clear, sharp pop. Valve closure shall be clear and sharp when the inlet pressure is reduced to the blowdown pressure. Type III valves shall open/close gradually, without instability, in response to the increase/decrease in pressure over the opening pressure.

7.4 Hydrostatic Shell Test Pressure—The valve shall show no signs of external leakage, permanent deformation, or structural failure when subjected to the hydrostatic shell test pressure specified in 8.2.

7.5 Set Pressure Tolerance—For all types of valves, the set pressure tolerance, plus or minus, shall not exceed the following: 2 psi for set pressures up to 70 psig, 3 % for set pressures over 70 psig up to 300 psig, 10 psi for set pressures over 300 psig up to 1000 psig, and 2 % for set pressures over 1000 psig.

7.6 Accumulation—Valves shall be sized to pass the specified flow (see 5.1.6) without permitting the inlet pressure (source static pressure) to rise beyond the accumulation pressure. The accumulation (overpressure) shall not exceed 10 % of set pressure, or 3 psi, whichever is greater. The valve shall show no signs of instability.

7.7 Blowdown Limits—Unless otherwise specified in the ordering data (see 5.1.8), valves shall operate satisfactorily with the following blowdown pressure setting:

7.7.1 For Type I and Type II valves, the maximum blowdown limit shall be 3 psi or 7 % of the set pressure, whichever is greater.

7.7.2 For Type III valves, the maximum blowdown limit shall not exceed 15 % of the set pressure or 3 psi, whichever is greater.

7.8 Seat Tightness—With an inlet pressure at or above the minimum allowable blowdown pressure setting, the valve shall seat tightly. No through seat leakage under this condition shall be allowed (see Table 15).
7.9 Installation Limitation—Valve operation shall not be adversely affected (loss of capacity or instability) by an inlet piping pressure loss of up to 25 % of the relief valve maximum permitted blowdown or an outlet piping break-pressure buildup of up to 10 % of the set pressure, or both. Where the installation will subject the valve to more severe piping restrictions, this information shall be noted in the ordering data (see 5.1.7).

7.10 Effective Discharge Area \((A)\)—Valves shall meet the effective discharge areas \((A)\) specified in Table 16 based on flow tests and neglecting any inlet/outlet losses (in accordance with API Standard RP520, Part 1, Appendix C).

Note 1.—To calculate the required effective discharge area for a given relief capacity requirement, see the following examples for steam, gas, and liquid services (for additional details, refer to API RP520, Part 1, Appendix C).

Note 2.—The formulae shown in Examples 1, 2, and 3 are for valves with vented/exposed spring construction bonnets. Nonvented bonnet valves generally have much lower capacity and the valve manufacturer should be consulted to obtain their capacities. Also, the calculated effective discharge area does not include impact as a result of installation limitation in accordance with 7.9.

Example 1, Steam Service:
Given: Flow medium = saturated steam
Upstream pressure = 100 psig
Accumulation = 10 %
Required flow through valve = 1774 lb/h
Calculate: \(A\) (effective discharge area of valve)

For steam service, use formula "C-10" in API RP520, Part 1, Appendix C

\[
A = \frac{W}{50P_1K_{SH}} \tag{1}
\]

where:
\(A\) = effective discharge area of valve, in.\(^2\);
\(W\) = required flow through valve, lb/h;
\(P_1\) = upstream relieving pressure, psia = 124.7 at 100-psig set pressure; and
\(K_{SH}\) = correction factor as a result of amount of superheat in steam = 1.0 for saturated steam.

Then substituting these values in Eq 1,

\[
A = \frac{1774}{50 \times 124.7 \times 1.0} = 0.285 \text{ in.}^2 \tag{2}
\]

Example 2, Air Service:
Given: Flow medium = air
Upstream pressure = 100 psig
Accumulation = 10 %
Temperature = 60°F
Required flow through valve = 556 SCFM
Calculate: \(A\) (effective discharge area of valve)

For air service, use formula "C-3" in API RP520, Part 1, Appendix C

\[
A = \frac{1774}{50 \times 124.7 \times 1.0} = 0.285 \text{ in.}^2 \tag{2}
\]
8.3 Set Pressure, Blowdown, and Seat Tightness Test—Inlet pressure (see Table 15 for test medium) shall be increased until the valve opens. Inlet pressure shall be reduced until the valve reseats. Leakage shall be checked over a 3-min period at an inlet pressure equal to the minimum allowable blowdown pressure setting. There shall be no damage to seating surfaces and no instability (chatter). The valve shall conform to the requirements in accordance with 7.5, 7.7, and 7.8.

9. Marking

9.1 Each valve shall be plainly and permanently marked by the manufacturer with the required data in such a way that the marking will not be obliterated in service. The marking may be placed on the valve or on a corrosion-resistant plate permanently attached to the valve. The following data is required:

9.1.1 Name of the manufacturer,
9.1.2 Manufacturer’s design or type number,
9.1.3 Valve specification code,
9.1.4 Size _____in. (nominal pipe size of the valve inlet),
9.1.5 Set pressure _____psi,
9.1.6 Rated relieving capacity (as applicable): Note 3—The information listed in 9.1.5 and 9.1.6 must be placed on a corrosion-resistant plate permanently attached to the valve.

9.1.6.1 Pounds per hour of saturated steam at an overpressure of 10 % of set pressure or 3 psi, whichever is greater, for valves used in steam service; or
9.1.6.2 Gallon per minute of water at 70°F at an overpressure of 10 % of set pressure or 3 psi, whichever is greater, for valves used in water service; or
9.1.6.3 SCFM (standard cubic feet per minute at 60°F and 14.7 psia) of air at an overpressure of 10 % of set pressure or 3 psi, whichever is greater, for valves used in air or gas service.
9.1.6.4 For Type I valves (where the outlet size is larger than the inlet size), the effective orifice area letter designation in accordance with API 526 must be stamped.
9.1.7 Service fluid (line medium),
9.1.8 Manufacturers’ serial number identifying the valve. The serial number should be stamped on the body and placed adjacent to the nameplate,
9.1.9 Range of set pressure adjustment.
9.2 All connections (inlet, outlet, drain, and so forth) shall be permanently marked to aid in correct installation of the pressure relief valve.

10. Quality Assurance System

10.1 The manufacturer shall establish and maintain a quality assurance system which will ensure that all the requirements of this specification are satisfied. This system shall also ensure that all valves will perform in a similar manner to those representative valves subjected to original testing for determination of the operating and flow characteristics.

10.2 A written description of the system the manufacturer will use shall be available for review and acceptance by the purchaser or his designee.

Note 4—If supplementary requirement S4 is specified in 5.1.10, an
10.3 The purchaser or his designee reserves the right to witness the production tests and inspect the valves in the manufacturer’s plant to the extent specified on the purchase order.

**SUPPLEMENTARY REQUIREMENTS**

One or more of the following supplementary requirements S1, S2, S3, S4, or S5 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing between the manufacturer and the purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

**S1. Examinations**

S1.1 Examination of Materials—Materials used in the manufacture of valves shall be examined to determine conformance to 6.3.1. Contracting agencies or their representatives shall normally accept certifications that the material complies with the specification; however, testing to demonstrate compliance may be required.

S1.2 Visual and Dimensional Examination—Visual and dimensional examination on sample valves shall be conducted to determine conformance with the ordering data, interface dimensions, and workmanship without disassembly.

S1.3 Nondestructive Tests—When nondestructive tests such as radiography, magnetic particle, or dye penetrant tests are required, they shall be specified in the ordering information (see 5.1.10).

**S2. Initial Qualification Testing**

S2.1 Rated Relieving Capacity Test—The valve-rated relieving capacity data shall be obtained and certified by the manufacturer by following the procedures outlined in Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.2 Endurance Test—The valve shall be cycled with the pressurized test medium (see Table 15 for the test medium) 50 times. After each ten cycles, the set pressure and the leakage shall be checked. Valve shall conform to the requirements specified in 7.5 and 7.8. There shall be no signs of instability or damage to the seating surface.

S2.3 Mechanical Shock Test—The valve shall be tested in accordance with the requirements of Grade A, Class I of MIL-S-901. The valve shall be pressurized during test. There shall be no structural damage or degradation to performance capability.

S2.4 Vibration Test—The valve shall be tested in accordance with Type I of MIL-STD-167-1. At frequencies up to and including 33 Hz (unless otherwise specified in the ordering information, see Section 5), there shall be no structural damage or degradation to performance.

S2.5 Stuck Valve Test—With the valve set at the specified set pressure, and not subjected to any inlet pressure, the valve shall be left in the closed position for a minimum of 72 h. After this 72-h period, the inlet pressure (see Table 15 for test medium) shall be increased until the valve opens. Valve shall conform to the requirement specified in 7.5.

**S3. Valve Testing With Imposed Installation Limitations**

S3.1 The test set up shall impose an inlet piping pressure loss of 25% of the blowdown (or the maximum inlet piping pressure loss, when specified in 5.1.7), and an outlet piping pressure buildup of 10% of set pressure (or the maximum outlet piping pressure buildup, when specified in 5.1.7). Tests outlined in 8.3 and S2.1 should be conducted to verify conformance to 7.5-7.9.

**S4. Quality Assurance**

S4.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.

S4.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.

S4.3 Organization—An organization chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility, the authority, and the organizational freedom to identify quality control problems, and to initiate, recommend, and provide solutions.

S4.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.

S4.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.

S4.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.

S4.7 Material Control—The manufacturer shall include a system for material control which ensures that the material
received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system that identifies inspection status of material throughout all stages of manufacture. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.

S4.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions using documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.

S4.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.

S4.10 Welding—The quality control system shall include provisions for ensuring that welding is in accordance with specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made available to the inspection authority if required.

S4.11 Nondestructive Examination—Provisions shall be made to use nondestructive examination as necessary to ensure that material and components comply with the specified requirements. Nondestructive examination operations shall be conducted by a recognized national body, and their qualification records shall be made available to the inspection authority if required.

S4.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in accordance with the specified requirements.

S4.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.

S4.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of material during all stages of manufacture and shall be able to distinguish between inspected and noninspected material.

S4.15 Calibration of Measurement and Test Equipment—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring, and test equipment to be used in verifying accordance with the specified requirements. Such calibration shall be traceable to a national standard and calibration records shall be maintained.

S4.16 Records Maintenance—The manufacturer shall have a system for the maintenance of inspection records, radiographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S4.17 Sample Forms—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S4.18 Inspection Authority—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with originals or copies of such documents.

S5. High-Integrity Body Valves

S5.1 These valves shall meet all the requirements of Type III construction. In addition, they shall have pressure-tight bonnet construction and not have any penetrations in the valve body. An accumulation of 25 % is permissible. The maximum blowdown limit shall not exceed 15 % of the set pressure or 8 psi, whichever is greater. These valves need not have the adjustable blowdown feature.

APPENDIX

X1. GUIDELINES FOR SELECTION AND INSTALLATION OF PRESSURE RELIEF VALVES

X1.1 Scope—This appendix provides general guidance for the selection and installation of pressure relief valves for shipboard use, and therefore, its use does not in any way relieve a shipbuilder of the final responsibility in the selection and installation of pressure relief valves. This appendix does not apply to boiler safety valves or hydraulic system relief valves.

X1.2 General—A properly designed, applied, and installed pressure relief valve will begin to lift at a definite pressure (set pressure), attain rated lift at a definite overpressure (accumulation pressure), and subsequently reseat at a definite lower pressure (blowdown pressure) once the overpressure condition at the source is corrected. For the pressure relief valve to function properly, the pressure at the source and the pressure differential that tends to hold the pressure relief valve disk in the open position must be the same (within certain limits) under all flowing conditions. Unstable operation (chatter) of a properly designed but improperly installed relief valve will occur when the pressure differential across the valve is not
maintained during flowing conditions. This can result from any one of the following (or a combination of the following) causes:

**X1.2.1 Restricted Inlet Piping**—The inlet piping restricts flow to the pressure relief valve, and sufficient flow from the source to the pressure relief valve cannot be sustained.

**X1.2.2 Restricted Source**—The flow generated by the source because of a particular failure is not sufficient to sustain the required pressure at the pressure relief valve inlet.

**X1.2.3 Restricted Discharge**—The outlet piping restriction results in a high backpressure buildup in the pressure relief valve outlet section to affect valve operation.

**X1.3 Restricted Inlet Piping**—The pressure relief valve is intended to control or limit the source pressure; however, the only pressure that it actually senses, and therefore, reacts to at any given instant, is the pressure immediately under the disk. Actually, it responds to the pressure differential between the valve inlet and valve outlet acting across the unbalanced disk area. The effect of any valve outlet pressure will be considered in X1.5. Therefore, for the pressure relief valve to function properly in response to a source condition, the pressure under the pressure relief valve disk must accurately reflect the pressure at the source at all times and under all flowing conditions. Before lift, the source pressure and the pressure under the disk are identical, since there is no flow of pressure medium. However, once the valve lifts and begins to relieve (discharge) fluid, there will be a pressure differential or pressure drop between the source pressure and the pressure under the disk, caused by the head loss through the inlet piping. If this pressure drop is small relative to the blowdown of the valve, the valve will remain open and continuously discharge fluid until the pressure at the source is reduced below the set pressure and normal and stable valve operation should result.

**X1.3.1 However, where the relief operation is limited by the inlet piping, the pressure drop during discharge may exceed the valve blowdown. If the pressure under the disk drops below the blowdown setting, the valve will immediately reseat as soon as it opens, even though the source pressure may still be above the set pressure or continuing to rise. Once the valve reseats, the valve stops relieving the fluid, and the pressure under the disk will immediately rise to match the source pressure. Assuming that the quantity of fluid discharged during this brief opening was not sufficient to bring the source pressure down below the set pressure, the valve will immediately reopen and a rapid chattering cycle will begin. The chattering will continue until the pressure at the source is reduced, in stages, to a value below the set pressure. Note that the rated capacity of the pressure relief valve, and not the available source supply, is critical since the pressure relief valve actually establishes the instantaneous or transient flow rate. Therefore, if the installation of a pressure relief valve results in a pressure drop in the inlet piping at the rated flow of the valve which approaches or exceeds the blowdown value of the valve, and the valve responds to an overpressure condition of any duration, chattering may occur. A chattering operation of a pressure relief valve will have the following detrimental effects:

**X1.3.1.1 Damage to the valve (particularly the seating surfaces) and the attached piping.**

**X1.3.1.2 Lowered Capacity**—The actual effective relieving capacity of a chattering pressure relief valve will be far below its rated capacity, which is based on a continuous open valve.

**X1.3.2 To prevent instability, the following criteria for pressure relief valve inlet piping installation should be followed:** The inlet piping connecting a pressure vessel, tank, pipe main, and other equipment being protected to the pressure relief valve inlet should have a streamlined entrance and should be as large in diameter, short in length, and direct as possible. Any changes in direction (elbows, bends, and so forth) should be avoided. The inlet piping should be arranged and sized so that the total pressure drop in the inlet piping does not exceed 25% of the blowdown of the pressure relief valve with a flow rate equal to the rated capacity of the pressure relief valve. For example, if a pressure relief valve is set at 100 psig and has a 10% blowdown and a capacity rating of 50 gpm at 10% accumulation, then the inlet piping should be arranged and sized so that it will pass a flow of 50 gpm with a pressure drop not exceeding 2.5 psi.

**X1.3.3 From the above, it can be seen that a pressure relief valve with very precise or narrow blowdown characteristics generally requires an installation with a very short and direct connection to the source. On the other hand, in existing installations in which the inlet connection is restrictive, a wide blowdown setting (where practical, based on other considerations) can improve stability. Another solution, in cases in which existing restrictive inlet piping cannot be replaced, would be the installation of a pilot-operated valve sensing directly to the source pressure. Since such a sensing line is always a very low-flow system, the valve will normally respond to the actual system pressure. As such, the pressure under the valve disk should have little effect on operating stability.

**X1.3.4 Another possible solution to a chattering problem in an existing installation is the substitution of a smaller size pressure relief valve, where permissible, based on other considerations. From a pressure drop standpoint, decreasing the capacity of the pressure relief valve has the same relative effect as increasing the size of the inlet piping. Where such a substitution results in a stable operating pressure relief valve, it can actually increase rather than decrease the effective protective capacity of a pressure relief valve installation.**

**X1.4 Restricted Source**—Chatter or unstable operation can occur when the rate of excess flow generated by the source is insufficient to sustain the valve in the open position during an overpressure condition. The mechanics and effects of this condition are the same as those resulting from restricted inlet piping, the only difference being the basic cause. This condition of insufficiency can be the result of oversizing the pressure relief valve in error or by deliberately oversizing the pressure relief valve in an effort to be on the “safe side.” This condition can also result from applications in which the pressure relief valve size is based on some maximum excess flow condition (for example, wide open failure of an upstream regulating valve) and the overpressure condition in most cases is caused by a lesser failure (for example, damage to the regulating valve
seat) which results in far less excess flow requiring discharge. When the pressure relief valve is merely oversized, it should be replaced with a valve of the correct capacity. As noted earlier, if such a substitution results in the elimination of a chattering condition, the result could be an increase in the effective relief protection capacity. In cases in which a variety of failures can require widely differing relief capacities, consideration should be given to installing two or more smaller size pressure relief valves with staggered settings.

X1.5 Restricted Discharge—The backpressure at the outlet section of a pressure relief valve can have a detrimental effect on valve operation. Under backpressure conditions, the pressure relief valve capacity is reduced because the valve lift is reduced by the increased pressure over the valve disk. Ideally, a pressure relief valve should only respond to the inlet (or source) pressure. However in valves that do not have a special balanced construction, any increase in the backpressure (which will have the effect of decreasing the pressure differential available to hold the disk in the open position) can have a similar effect on valve operation as a drop in the valve inlet pressure. Also, superimposed backpressure can shift the effective set pressure of a pressure relief valve. The following criteria for pressure relief valve discharge piping installation should be followed: The discharge piping should be arranged and sized so that the built-up backpressure does not cause unsatisfactory pressure relief valve operation, either from a stability or capacity standpoint. In cases in which a built-up backpressure in excess of 10% of the set pressure, or where a superimposed backpressure can exist in the discharge line, a pressure relief valve of balanced design should be used.

X1.6 Pressure Relief Valve Setting—To ensure good valve operation, the spread between the maximum system operating pressure and the pressure relief valve set pressure should always be as wide as possible, consistent with economical and safe system design. Pressure relief valves are generally set to open at 10% above the operating pressure. This margin will improve seat tightness (by permitting a greater normal seating load), decrease the number of times the valve is required to operate, and decrease valve maintenance. It will permit using a wider blowdown band, which can result in a more stable valve operation. X1.6.1 The two critical performance points in any pressure relief valve installation are the accumulation pressure and the blowdown pressure. The accumulation pressure (the maximum overpressure which the pressure relief valve will permit the source to reach) establishes the required design rating of the equipment being protected. Therefore, the accumulation pressure must be compatible with economical and practical system and component design or with the ratings of systems and components already designed or installed. The blowdown pressure (the pressure, below the set pressure, to which the source must drop before the pressure relief valve will reseat) must always be above the maximum system operating pressure.

X1.6.2 From an economical point of view, the blowdown should be as short as possible. However, from the point of stable valve operation, a high blowdown is desirable. A compromise may therefore have to be accepted.

X1.6.3 If the blowdown pressure and the maximum system operating pressure are too close together, or if they can cross over, there is the possibility that a condition can be set up where, after responding to an overpressure, the system must be secured to stop the discharging of the pressure medium before the pressure relief valve will reseat. The higher the valve set pressure can be set above the maximum system operating pressure, the wider (or less precise) the spread between the accumulation and blowdown limits which can be permitted, and therefore, the less critical pressure relief valve operation becomes.

X1.6.4 Therefore, the selection and installation of pressure relief valve protection always involves compromises between system design considerations and pressure relief valve design considerations. As stated previously, the blowdown and accumulation are the only critical pressure relief valve performance points from a system standpoint. The actual set pressure is of little importance aside from providing a reference for setting and checking the valve. If the blowdown pressure and accumulation pressure meet system requirements, the set pressure can fall anywhere in between.

X1.7 Installation Forces—Forces transmitted to a pressure relief valve by thermal stresses, forced alignment of piping, and inadequate supports tend to distort the valve body. These forces should be avoided since the operation of pressure relief valves is particularly sensitive to such influences. The piping must also be designed and adequately supported to withstand the reactive forces associated with pressure relief valve discharge.

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Standard Specification for Rotary Positive Displacement Pumps, Commercial Ships Use

This standard is issued under the fixed designation F 1510; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification defines the requirements applicable to design and construction of rotary positive displacement pumps for shipboard use. The classes of service are shown in Section 4.
1.2 This specification will not include pumps for hydraulic service or cargo unloading applications.

2. Referenced Documents
2.1 ASTM Standards:
- A 27/A 27M Specification for Steel Castings, Carbon, for General Application
- A 36/A 36M Specification for Carbon Structural Steel
- A 48 Specification for Gray Iron Castings
- A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
- A 159 Specification for Automotive Gray Iron Castings
- A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service, or Both
- A 322 Specification for Steel Bars, Alloy, Standard Grades
- A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
- A 434 Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered
- A 449 Specification for Quenched and Tempered Steel Bolts and Studs
- A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate— and Higher-Temperature Service
- A 536 Specification for Ductile Iron Castings
- A 563 Specification for Carbon and Alloy Steel Nuts
- A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
- A 574 Specification for Alloy Steel Socket-Head Cap Screws
- A 582/A 582M Specification for Free-Machining Stainless Steel Bars
- B 150 Specification for Aluminum Bronze Rod, Bar, and Shapes
- B 584 Specification for Copper Alloy Sand Castings for General Applications
- D 1418 Practice for Rubber and Rubber Lattices—Nomenclature
- D 2000 Classification System for Rubber Products in Automotive Applications
- D 3951 Practice for Commercial Packaging
- F 104 Classification System for Nonmetallic Gasket Materials
- F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
- F 912 Specification for Alloy Steel Socket Set Screws
- F 1511 Specification for Mechanical Seals for Shipboard Pump Applications

2.2 ANSI Standard:
- B 16.5 Pipe Flanges and Flanged Fittings

2.3 SAE Standards:

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3.1.17 suction lift—a term used to define a pump’s capability to induce a partial vacuum at the pump inlet.

3.1.18 temperature, maximum allowable—the maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure. This pressure should not be greater than \( \frac{2}{3} \) of the hydrostatic test pressure of the pressure containing parts.

3.1.19 net positive inlet pressure available (NPIPA)—the total inlet pressure available from the system at the pump inlet connection at the rated flow, minus the vapor pressure of the liquid at the pumping temperature.

3.1.10 net positive inlet pressure required (NPIPR)—the net pressure above the liquid vapor pressure at rated flow and pumping temperature and at the pump inlet connection required to avoid performance impairment due to cavitation.

3.1.11 pressure, cracking—sometimes called set pressure, start-to-discharge pressure, or popping pressure—the pressure at which the relief valve just starts to open. This pressure cannot be determined readily if the relief valve is internal to the pump and it bypasses the liquid within the pump.

3.1.12 pressure, differential—the difference between discharge pressure and inlet pressure.

3.1.13 pressure, discharge—the pressure at the outlet of the pump. Discharge pressure is sometimes called outlet pressure.

3.1.14 pressure, inlet—the total pressure at the inlet of the pump. Inlet pressure is sometimes called suction pressure.

3.1.15 pressure, maximum allowable working—the maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified temperature. This pressure should not be greater than \( \frac{2}{3} \) of the hydrostatic test pressure of the pressure containing parts.

3.1.16 rated condition—defined by discharge pressure, inlet pressure, capacity, and viscosity.

3.1.17 rotary pump—a positive displacement pump consisting of a casing containing gears, screws, lobes, cams, vanes, shoes, or similar elements actuated by relative rotation between the drive shaft and the casing. There are no inlet and outlet valves. These pumps are characterized by their close running clearances.

3.1.18 slip—the quantity of fluid that leaks through the internal clearances of a rotary pump per unit of time. Slip depends on the internal clearances, the differential pressure, the characteristics of the fluid handled and in some cases, the speed.

3.1.19 speed, maximum allowable (in revolutions per minute)—the highest speed at which the manufacturers’ design will permit continuous operation.

3.1.20 speed, minimum allowable (in revolutions per minute)—the lowest speed at which the manufacturers’ design will permit continuous operation.

3.1.21 speed, rated—the number of revolutions per minute of the driving rotor required to meet the rated conditions.

3.1.22 suction lift—a term used to define a pump’s capability to induce a partial vacuum at the pump inlet.

3.1.23 temperature, maximum allowable—the maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure.

4. Classification

4.1 Pumps will be classified as follows:

4.1.1 Types:

4.1.1.1 Type II—Screws with timing gears.

4.1.1.2 Type III—Screws without timing gears.

4.1.1.3 Type IV—Impellers with timing gears.
4.1.4 Type V—External gear (spur, helical, herringbone, lobe).
4.1.5 Type VIII—Internal gear, internal rotary lobe.
4.1.6 Type X—Vane (sliding).
4.1.7 Type XI—Sliding shoe.

4.2 Classes:
4.2.1 Class A—Aqueous film forming foam, AFFF.
4.2.2 Class B—Bromine.
4.2.3 Class CD—Clean distillate fuel, viscosity 32 to 100 SSU (2 to 21 centistokes) (for example, jet fuel, JP-5, fuel).
4.2.4 Class CH—Clean heavy fuel, viscosity 100 to 1500 SSU (21 to 325 centistokes) (propulsion fuel).
4.2.5 Class DD—Dirty distillate fuel, viscosity 32 to 100 SSU (2 to 21 centistokes) (for example, transfer, stripping, purifier feed, leak-off).
4.2.6 Class DH—Dirty heavy oil, viscosity 32 to 4000 SSU (2 to 863 centistokes) (for example, waste oil, transfer, stripping, purifier feed, leak-off).
4.2.7 Class G—Gasoline, aviation gasoline, gasohol.
4.2.8 Class LM—Lube oil, viscosity 130 to 4000 SSU (27 to 863 centistokes) (for example, propulsion, SSTG, control, L.O. service).
4.2.9 Class LA—Auxiliary L.O. 130 to 4000 SSU (27 to 863 centistokes) service and L.O. transfer.
4.2.10 Class M—Miscellaneous.
4.2.11 Class W—Heavily contaminated seawater, viscosity 32 to 4000 SSU (2 to 863 centistokes) (bilge stripping, oily waste transfer).

5. Ordering Data
5.1 The ordering activity shall provide manufacturers with all of the following information:

5.1.1 Title, number, and date of specification,
5.1.2 Type and classification, see Section 4,
5.1.3 Capacity in gallons per minute or litres per minute at rated discharge pressure,
5.1.4 Discharge pressure in pound-force per square inch gage (psig) or kilopascal (kPa) gage,
5.1.5 Airborne noise levels (if different than 7.5),
5.1.6 Viscosity (only if different than Section 4),
5.1.7 Mounting configuration (vertical, horizontal),
5.1.8 Driver type (motor, turbine, engine, attached),
5.1.9 Driver characteristics or specifications, or both,
5.1.10 Relief valve cracking pressure and full-flow bypass pressure,
5.1.11 Packaging and boxing requirements (immediate use, domestic; storage, domestic; overseas),
5.1.12 Quantity of pumps,
5.1.13 Quantity of drawings,
5.1.14 Quantity of technical manuals,
5.1.15 Quantity of test reports,
5.1.16 Performance test, if required,
5.1.17 Certified data required, and
5.1.18 Instruction plates and locations, if required.

6. Materials
6.1 Pump component parts shall be constructed of the materials shown in Table 1.

6.2 Materials other than shown in Table 1 are considered exceptions and are subject to approval by the purchaser before usage.

7. General Requirements
7.1 Pumps shall be designed for a 20-year service life.
7.2 Pumps shall be capable of sustained operation during inclinations up to 45° in any direction.
7.3 The pumps shall be capable of withstanding environmental vibration induced by shipboard machinery and equipment in the frequency range from 4 to 25 Hz.
7.4 The internally excited vibration levels of the pump shall not exceed 0.003-in. (0.00762-mm) displacement peak to peak during rated operation when readings are measured on the pump case near the coupling perpendicular to the pump shaft.
7.5 At normal operating conditions, the airborne noise level of the pump shall not exceed 85 dBA.
7.6 The pump driver (electric motor, air motor, turbine, hydraulic motor, diesel engine, attached) shall be as specified in the ordering data. The driver shall be sized for maximum flow at the relief valve full-flow bypass pressure, at maximum viscosity. If a two-speed motor is specified for high-viscosity Class LM applications, the motor size shall be based on power required at low speed, which is used during cold startup.
7.7 If a reduction gear is required between the driver and the pump, it shall be provided by the pump manufacturer. Reduction gears shall meet the requirements of AGMA 390.03. Gears shall be AGMA Class 7 or better, pinions shall be AGMA Class 8 or better, and bearings shall be designed for a L10 life of 15,000 h.
7.8 Horizontal pumps may be mounted on a common horizontal bedplate with the driving unit or mounted directly to the driver. Vertical pumps may be mounted with a bracket to the driving unit or mounted directly to the driver.
7.9 All pump units shall incorporate guards over couplings, belts, and other external rotating parts.
7.10 The mounting arrangement shall be sufficiently rigid to assure alignment is maintained between the pump and the driver in accordance with the conditions in 7.2, 7.3, and 8.1.
7.11 Seating surfaces of mounting bedplates, bracket mounting plates, or other mounting arrangements shall be machined.
7.12 Mounting bedplates, brackets, and plates shall be provided with holes of sufficient size and quantity to assure adequate attachment to shipboard foundation or mounting structure.
7.13 Vertical units with face mounted motors shall be arranged so there are four (4) possible orientations of motor driver to pump. Other drivers are to be oriented in accordance with the ordering information.
7.14 Vertical units that are motor driven shall be assembled with the conduit box mounted over the pump inlet flange, unless otherwise specified.
7.15 Couplings between the pump and the driver shall be keyed to both shafts.
7.16 Alignment between the pump and the driver shall not exceed 0.005-in. (0.13-mm) offset and 0.0005-in./in. (0.01-mm/mm) angularity.
7.17 An external (separate) relief valve shall not be provided with the pump unless otherwise specified. The purchaser shall provide the cracking pressure and the fullflow bypass pressure of the system relief valve to the pump manufacturer.

7.18 Direction of rotation shall be indicated by an arrow cast into the pump or by a label plate attached to the pump.

7.19 Inlet and outlet connections shall be indicated by a label plate attached to each flange.

8. Pump Design

8.1 Pump inlet and outlet connections shall be flanged. Steel case pump flanges shall be in accordance with ANSI B16.5 raised face. Cast gray iron and nonferrous material cases shall be in accordance with ANSI B16.5 flat face, unless otherwise stated in the ordering data. Flanged connections shall meet the requirements in API Standard 676, Paragraph 2.4.7. Spool...
piece adapters (threaded and seal welded, or O-ring sealed to the pump case on one end and flanged on the other end) may be furnished to meet the flanged inlet and outlet requirement.

8.2 Pump cases shall be equipped with vent, drain, inlet, and outlet gage connections. The connection shall be straight thread with an O-ring seal. Tapered pipe thread connections are prohibited. Small pumps do not require vent, drain, and gage connections.

8.3 Materials for the pump shall be compatible with the fluid being pumped, and the operating parameters to be encountered including maximum pressure and temperature extremes stated in the ordering data.

8.4 Pumps shall be equipped with radial and thrust bearings as necessary to counteract any unbalanced forces in the pump and to ensure that the pump will operate satisfactorily in accordance with 7.2.

8.5 Bearings shall be securely fitted (by snap rings, shoulders, or other means) to prevent axial movement. Bearing housings shall be integral to the pump case or secured to the pump case in such a manner as to ensure alignment. Usage of bolts alone is not considered sufficient to ensure alignment.

8.6 Bearings may be sealed and self-lubricated or externally lubricated or may be lubricated by the liquid being pumped.

8.7 Rolling contact bearings shall be selected in accordance with AFBMA standards and shall have a minimum L10 life of 15 000 h as calculated in accordance with AFBMA Standard 9 or 11 as appropriate.

8.8 Pumps shall be equipped with mechanical shaft seals, in accordance with Specification F 1511. The installation shall ensure that adequate circulation of liquid at the seal faces occurs to minimize deposit of foreign matter and provide adequate lubrication of the seal faces.

8.9 Mechanical seals shall be positioned or located on the shaft axially, by a positive means such as a stub, step, or shoulder positively located on the pump shaft. Set screws shall not be used to position seals or seal sleeves axially. An antirotation pin may be provided to prevent the mechanical seal-mating ring from rotating.

8.10 When required by the ordering data, the pump shall be equipped with a backup packing box. The design shall allow for installation of two or more rings of packing for use in the event of a mechanical seal failure. The packing rings shall be able to be inserted without having to remove the mechanical seal.

8.11 Pump head or end covers, or both, shall be located to the pump case by a means such as rabbot, dowels, or pilot to ensure proper alignment.

8.12 Rotors and timing gears shall be machined and positively secured in position to maintain required clearances and prevent undue wear.

8.13 Fasteners shall be selected from Table 1 taking into consideration temperature of operation, mechanical properties, and corrosion resistance.

9. Performance Requirements

9.1 Pumps shall deliver the rated capacity at 10-psia (69-kPa absolute) inlet pressure while operating at the parameters specified in the ordering data.

9.2 The maximum capacity of the pump shall not exceed the amount determined by the following formula:

\[
Q_{\text{max}} = Q \left[ 1 + \frac{1}{Q_{\text{F}}^2} \right]^{0.4}
\]

where:

- \(Q\) = rated capacity and
- \(Q_{\text{max}}\) = maximum allowable capacity, at minimum viscosity. \(Q_{\text{max}}\) shall be rounded to the nearest whole number.

9.3 Capacity of all classes (except DH) pumps shall not be less than the value stated in 5.1.3 at the rated conditions, with minimum viscosity.

9.4 Class DH pumps shall meet the capacity requirements at 4000 SSU (863 centistokes) and shall not be damaged by continuous operation at 32 SSU (2 centistokes).

9.5 Class LM & LA pumps shall meet the capacity requirements at 130 SSU (27 centistokes) and driver horsepower shall be determined based on 4000 SSU (863 centistokes).

10. Painting and Coatings

10.1 Painting—External unmachined and nonmating machined surfaces shall be thoroughly cleaned and painted.

10.2 Painting external surfaces of nonferrous parts and components is not required but is permissible to avoid excessive masking. Identification and information plates shall not be painted or oversprayed.

11. Equipment Identification and Instruction Plates

11.1 Identification plates shall be made of brass or stainless steel and furnished on each pump unit.

11.2 Instruction plates shall be made of brass, stainless steel, or plastic when furnished on each pump unit.

11.3 Plates shall be secured to equipment with corrosion-resistant metallic fasteners.

11.4 Pump unit identification plates shall contain data as follows:

11.4.1 Manufacturer's name.

11.4.2 Manufacturer's model or type and size.

11.4.3 Service application.

11.4.4 Manufacturer's serial number.

11.4.5 Salient design characteristics if applicable.

11.4.5.1 Capacity.

11.4.5.2 Discharge pressure.

11.4.5.3 Pump rated speed (RPM).

11.5 Accessory units such as the driver, controller, pump, and gearbox, shall have an identification plate in accordance with the applicable equipment specification. If not specified, the manufacturer shall use its commercial nameplate.

12. Testing Requirements

12.1 General—All equipment shall be tested in accordance with 12.2 and 12.3. The first unit of a new design or size shall be tested in accordance with 12.4 and 12.5.

12.1.1 Equipment for specified tests shall be provided by the manufacturer.
12.1.2 Acceptance of tests does not constitute a waiver of requirements to meet performance under specified operating conditions, nor does inspection relieve the manufacturer of his responsibilities.

12.1.3 The manufacturer shall maintain a complete log of the tests performed and shall prepare the required number of copies of the test report, certified as to correctness.

12.2 Hydrostatic Test—Pressure-containing parts shall be tested hydrostatically with liquid at a minimum of 1 1/2 times the maximum allowable working pressure but at not less than 50-lb/in.² (345-kPa) gage. The hydrostatic test shall be considered satisfactory when no leaks are observed for a minimum of 5 min. Seepage past internal closures required for segmented casing testing and operating of the hydrostatic test pump to maintain pressure will be accepted.

12.3 Mechanical Running Test—The pump manufacturer shall conduct a test on all pumps to ensure that rated capacity is achieved at the rated condition. Such tests may be performed with other than the specified liquid if the viscosity is equal to the minimum viscosity for the class of pump being tested. A viscosity up to 50 SSU greater than the minimum viscosity may be used. Differential pressure may be measured in lieu of inlet pressure and discharge pressure.

12.4 Performance Test—The pump manufacturer shall operate a pump at the manufacturing facility or approved test facility to obtain complete test data when required by the ordering document (5.1.15). The pump shall be tested at rated speed, discharge pressure, viscosity, and 10-psia (69-kPa absolute) inlet pressure. The pump shall meet rated capacity at this condition and shall meet the airborne noise levels in 7.5. This test is normally required for new types, new designs, or new applications of pumps.

12.5 Certified Data—Certified performance data or curves shall be supplied when required, see 5.1.16.

13. Technical Documents

13.1 An outline or top drawing of the unit (pump and driver) shall be furnished. Length, width, height, mounting details, and connections shall be dimensioned.

13.2 Complete performance curves shall be furnished. The curves may be on graphs which can be printed on notebook size paper.

13.3 Pump drawings shall include a sectional assembly drawing. The sectional assembly drawing shall contain a complete list of materials or reference to a list of materials drawing, which shall be provided.

13.4 Brackets, bedplates, guards, couplings, identification plates, rotation arrows, and so forth shall be shown on the outline drawing.

13.5 Any subassembly made up of parts that require special alignment or assembly methods that cannot be disassembled, repaired, and reassembled onboard ship without the use of special tools and jigs shall be indicated as a subassembly in the list of material.

13.6 Drawings for driver and associated equipment shall be in accordance with their respective specifications.

13.7 The weight and center of gravity (calculated or actual) of the unit shall be indicated on the outline drawing.

13.8 Instruction books or technical manuals shall be prepared for each different type or size of pump installed. A single manual shall contain not more than one type or size of pump. However, when several pumps are installed in a ship that are identical except for type of driver, they may be included in a single manual.

13.9 Piece (item or find) numbers of parts referred to in technical manuals shall match the piece numbers shown on pump drawings.

13.10 Technical manuals shall contain reproductions of pump drawings.

13.11 Quantities of technical manuals shall be in accordance with the order.

14. Packaging and Preservation

14.1 Pumps, pump units, and accessories shall be packaged and preserved in accordance with Practice D 3951, and the following:

14.2 Preservation—Items susceptible to deterioration or damage from environmental elements shall be preserved. Noncoated ferrous surfaces shall be preserved.

14.3 Cushioning and Bracing—Items susceptible to damage during shipment and handling shall be cushioned or shall be securely braced or blocked, or both, within the shipping container, to avoid damage.

14.4 Container Marking—Containers, boxes, or packages shall be clearly marked with the ship to address, contract or purchase order number, shipping point address, and item nomenclature.

15. Keywords

15.1 positive displacement pump; pump; rotary pump; shipboard pump
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established by the U.S. Navy, Commander Naval Sea Systems Command (NAVSEA) shall apply when specified in the contract or purchase order. When there is a conflict between the specifications and this section, requirements of this section shall take precedence.

S1.1 Materials other than shown in Table 1 are considered exceptions and are subject to approval by NAVSEA.

S1.2 The pumps shall be capable of withstanding environmental vibration induced by shipboard machinery and equipment in the frequency range of 4 to 25 Hz and be in accordance with MIL-STD-167, Type 1. Maximum single frequency displacement (double amplitude) in the 4- to 15-Hz range is 0.060 in. (1.524 mm) and in the 16- to 25-Hz range is 0.040 in. (1.016 mm).

S1.3 The internally excited vibration levels of the pump shall be in accordance with MIL-STD-167, Type II and shall not exceed 0.003-in. (0.076-mm) displacement peak to peak during rated operation when readings are measured on the pump case near the coupling perpendicular to the pump shaft.

S1.4 At the conditions in Section 9, the airborne noise level of the pump unit shall meet the requirements in Table S1.1 (see MIL-STD-740-1).

S1.5 At the conditions in Section 9, the structureborne noise level of the pump unit shall meet the requirements in Table S1.2 (see MIL-STD-740-2).

S1.6 Pumps shall meet the requirements of MIL-S-901 HI (High Impact) Shock, Grade A.

S1.7 Mechanical shaft seals shall be in accordance with Specification F 1511, including Supplement S1. An anti-rotation pin shall be provided for seal O-ring mating rings in shaft sizes 1” and larger, when the pump will be handling viscous fluids over 130 ssu (27 centistrokes). Pin diameter and length shall be compatible with the slot in the ring.

S1.8 Qualification Tests—The first pump of each size, type, or design shall meet the following qualification tests. All tests shall be performed with the motor size required at rated condition as indicated in Section 9.

S1.9 Performance Test—The pump shall be tested at the conditions in Section 9 to demonstrate that the pump is capable of delivering the required capacity. Record all test data including electrical power input for comparison to performance retest results (see S1.15).

S1.10 Vibration Type II Test—The pump shall be tested to demonstrate the ability to meet the requirements of S1.3. Record all test data, including electrical power input, for comparison to performance retest results (see S1.15).

S1.11 Noise Tests—The pump shall be tested to demonstrate the ability to meet the requirements of S1.4 and S1.5. Record all test data, including electrical power input, for comparison to performance retest results (see S1.15).

S1.12 Vibration Type I Test—The pump shall be tested to demonstrate the ability to meet the requirements of S1.2.

S1.13 Shock Test—The pump shall be tested to demonstrate the ability to meet the requirements of S1.6.

S1.14 Endurance Test—The endurance test shall consist of a running test of not less than 500 h of actual running time at rated condition. The 500 h shall be broken by at least three rest periods of 8 h or more each. A minimum of ten start-stop cycles shall be performed during the course of the test.

S1.15 Performance Retest—Upon completion of the tests in S1.9 through S1.14, repeat the performance test (S1.9), the Vibration Type II test (S1.10), and the noise test (S1.11). Record all test data.

S1.16 Test Reports—A test report shall be submitted for each test conducted. Quantity and format as defined in the ordering data.

| TABLE S1.1 Acceptable Octave Band Sound Pressure Levels (in dB re 20 µPa) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Octave Band Center Frequency, Hz | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| 91 | 91 | 88 | 85 | 82 | 79 | 76 | 73 | 70 | 67 |
### TABLE S1.2 Acceptable Structureborne Vibratory Acceleration Acceptance Criteria in Adbe re 10 µm/s² (Reference MIL-STD-740–2)

<table>
<thead>
<tr>
<th>Octave Band Center Frequency in Hz</th>
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<th>Solidly mounted pumps</th>
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Standard Specification for
Mechanical Seals for Shipboard Pump Applications

This standard is issued under the fixed designation F 1511; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers mechanical end-face seals for centrifugal and positive displacement pumps for shipboard use.

1.2 The following types of seals are not included in this specification: lip seals, oil seals, circumferential seals, or labyrinth seals.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only. A companion hard metric standard is in the process of preparation.

1.4 Special requirements for U.S. Navy Shipboard Pump Applications are included in Supplement S1.

2. Referenced Documents

2.1 ASTM Standards:

A 108 Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality
A 182/A182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A 276 Specification for Stainless Steel Bars and Shapes
A 313/A 313M Specification for Stainless Steel Spring Wire
A 351/A351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts
A 436 Specification for Austenitic Gray Iron Castings
A 494/A494M Specification for Castings, Nickel and Nickel Alloy
A 564/A564M Specification for Hot-Rolled and Cold-Finished Age-Hardenig Stainless Steel Bars and Shapes
A 579 Specification for Superstrength Alloy Steel Forgings
A 693 Specification for Precipitation-Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
A 705/A705M Specification for Age-Hardenig Stainless and Steel Forgings
A 744/A744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
B 62 Specification for Composition Bronze or Ounce Metal Castings
B 127 Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire
B 166 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire
B 168 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip
B 271 Specification for Copper-Base Alloy Centrifugal Castings
B 333 Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip
B 335 Specification for Nickel-Molybdenum Alloy Rod
B 338 Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
B 348 Specification for Titanium and Titanium Alloy Bars and Billets
B 367 Specification for Titanium and Titanium Alloy Castings
B 443 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip
B 446 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar
B 472 Specification for Nickel Alloy UNS N06030, UNS N06022, UNS N06200, UNS N08020, UNS N08026, UNS N08800, UNS N08801, UNS N08802, and UNS N08803

This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.
N08024, UNS N08926, UNS N08367, UNS N10276, UNS N10665, UNS N10675 and UNS R20033 Nickel Alloy Billets and Bars for Reforging
B 473 Specification for UNS N08020, UNS N08024, and UNS N08026 Nickel Alloy Bar and Wire
B 505 Specification for Copper-Base Alloy Continuous Castings
B 584 Specification for Copper Alloy Sand Castings for General Applications
B 637 Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service
B 670 Specification for Precipitation-Hardening Nickel Alloy (UNS N07718) Plate, Sheet, and Strip for High-Temperature Service
D 1141 Specification for Preparation of Substitute Ocean Water
D 1418 Practice for Rubber and Rubber Latices Nomenclature
D 3294 Specification for Polytetrafluoroethylene (PTFE) Resin Molded Basic Shapes
D 3951 Practice for Commercial Packaging
2.2 ASQ Standards:
2.3 ANSI Standards:
Y14.1 Drawing Sheet Size and Format
Y14.2 Line Convention and Lettering
Y14.3 Multi and Sectional View Drawings
Y14.5 Dimensioning and Tolerancing for Engineering Drawings
Y14.6 Screw Thread Representation
Y14.26.3 Computer-Aided Preparation of Production Definition Data, Terms and Definitions
2.4 Military Standards:
MIL-S-901 Shock Tests, H.I. (High Impact); Shipboard Machinery, Equipment & Systems, Requirements for
MIL-P-16789 Packaging of Pumps, Including Prime Movers and Associated Repair Parts
MIL-R-83248 Rubber Fluorocarbon Elastomer, High Temperature, Fluid, and Compression Set Resistant
MIL-STD-167-1 Environmental Vibration Testing
2.5 ISO Standard:
2.6 Other Document:
Metals and Alloys — Unified Numbering System-DS-56f
3. Terminology
3.1 Refer to Annex A1 for terminology relating to mechanical seals.
4. Classification of Seal Arrangements
4.1 For this specification, mechanical seals shall be classified by type, grade, and class. The categories are divided by application arrangement in the equipment in which it is installed:
4.1.1 Type A—Inside Single Mounted Seals
4.1.2 Type B—Outside Single Mounted Seals
4.1.3 Type C—Double Seals
4.1.4 Type D—Tandem Seals
4.1.5 Type E—Gas Seals
4.1.6 Type F—Special Arrangements/Applications Vacuum or Gas Seal
4.1.7 Grade 1—Basic End Face Seal
4.1.8 Grade 2—Cartridge Seal
4.1.9 Grade 3—Split Seal
4.1.10 Class 0—Nonsplit Seal Assembly
4.1.11 Class 1—Partial Split Seal Assembly, Solid Gland
4.1.12 Class 2—Partial Split Seal Assembly, Split Gland
4.1.13 Class 3—Fully Split Seal Assembly, Solid Gland
4.1.14 Class 4—Fully Split Seal Assembly, Split Gland
4.2 Figs. 1-6 give general orientation information for various types of seals. The specific design of seal shown is not limited to that particular application.
5. Ordering Information
5.1 The purchaser (buyer) shall provide the manufacturer with all of the pertinent application data shown in Figs. 7-9. If special operating conditions exist that are not shown in the checklist, they shall also be described.
6. Material
6.1 Mechanical seals shall be constructed of materials selected from Tables 1-3 after reviewing temperature, pressure/velocity (PV), and corrosion resistance requirements for all parts for each application.
6.2 Metal Components:
6.2.1 Mechanical seal metal parts in contact with the pumped liquid shall be compatible with their environment.
6.2.2 Table 1 identifies metal component compatibility.
6.2.3 Material specifications:
FIG. 1 Single Seal—Inside Bellows Secondary Seal, Classification Type A Grade 1

FIG. 2 Single Seal—Inside O-Ring Secondary Seal, Classification Type A Grade 1
FIG. 3 Single Seal—Outside Mounted Classification Type B Grade 1

FIG. 4 Double Seals—Back to Back Classification Type C Grade 1
FIG. 5 Double Seals—Face to Face Classification Type C Grade 1

FIG. 6 Tandem Seals Classification Type D Grade 1
1.1 Seal Description
Type __________________________ Grade __________________________

1.2 Pump Description
Pump Mfg. __________________________ Model __________________________ Size __________________________
Pump S/N __________________________
Pump Type (horizontal, vertical, etc.) __________________________
No. of Stages __________________________
Sleeve or Shaft Mat’l __________________________ Casting Mat’l __________________________
Cooling Water Available? Yes No F ___________ GPM ___________
Stuffing Box Water Jacketed? Yes No
Is Face of Stuffing Box Machined? Yes No

FILL OUT STUFFING BOX DIMENSIONS SHOWN ON FIG. 6

2.1 Liquid Pumped
Fluid __________________________ Concentration __________________________ Specify for unique cargo pump fluid application

Pumping Temperature (°F) ___________ Normal ___________ Max ___________ Min ___________

Specific Gravity at Operating Condition ___________
Viscosity Range at Operating Conditions Temp. ___________ SSU ___________
Vapor Pressure at Operating Conditions Pressure ___________ psig ___________
Corrosion/Erosion Caused by ___________
Abrasive Separator To be Supplied—Yes No

2.2 Operating Conditions
Rated Discharge Pressure Max (psig) ___________
Suction Box Pressure Range (psig) ___________
Stuffing Box Pressure Range (psig) ___________
Stuffing Box Temperature Max (°F) ___________
Hydrostatic Test Pressure (psig) ___________
Speed (rpm) ___________
Direction of Rotation From Drive End CW or CCW ___________

3.1 Preservation and Packaging
Special Preservation & Packaging for Storage & Shipment ___________

4.1 Other Special Requirements
Seal Manufacturer’s Certification of Compliance Required—Yes No

5.1 US Navy Application Requirements
Supplement S1—Yes No

Check applicable dimensional Table below:
Table No. S1, Standard Long Mechanical Seal ___________
Table No. S2, Standard Short Mechanical Seal ___________
Table No. S3, Special Cartridge Seals Grade 2 ___________
Table No. S4, Special Seals Grade 1 ___________

FIG. 7 Ordering Data Checklist

<table>
<thead>
<tr>
<th>Material</th>
<th>ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper alloy</td>
<td>B 271, B 584, B 505</td>
</tr>
<tr>
<td>Bronze</td>
<td>B 62</td>
</tr>
<tr>
<td>Alloy 20</td>
<td>B 472 and B 473 (UNS N08020, N08026)</td>
</tr>
<tr>
<td>316 stainless steel</td>
<td>A 240/A 240M, A 276, and A 313/A 313M (UNS S316XX)</td>
</tr>
<tr>
<td>304 stainless steel</td>
<td>A 182/A 182M, A 313/A 313M (UNS S304XX), A 351/A 351M (CF3, 3A, CF8, 8A, CF8C, CF10)</td>
</tr>
<tr>
<td>Alloyed stainless steel (cast)</td>
<td>A 744/A 744M (CN-7M, CN-7MS)</td>
</tr>
<tr>
<td>17-4 PH</td>
<td>A 564/A 564M and A 693 (UNS S17400)</td>
</tr>
<tr>
<td>AM 350</td>
<td>A 579 (Grade 61)</td>
</tr>
<tr>
<td>NiCu</td>
<td>B 164 (UNS N04400, N04405), B 127, A 494/A 494M (Grades M35-1, M35-2, M30H, M-25S)</td>
</tr>
<tr>
<td>NiMo</td>
<td>A 494/A 494M (Grades CW-2M, N-12 MV)</td>
</tr>
<tr>
<td>NiMo (Alloy B)</td>
<td>B 333 and B 335 (UNS N10001, N10665, N10675)</td>
</tr>
<tr>
<td>NiCrFe</td>
<td>NiCrMoCo</td>
</tr>
<tr>
<td>NiCr</td>
<td>B 166, B 168</td>
</tr>
<tr>
<td>NiCrMoCo</td>
<td>A 637, B 670</td>
</tr>
<tr>
<td>NiCrMoC</td>
<td>A 443, B 446</td>
</tr>
<tr>
<td>Steel</td>
<td>A 108</td>
</tr>
<tr>
<td>Austenitic grey iron</td>
<td>A 436</td>
</tr>
<tr>
<td>Titanium</td>
<td>B 338, B 348, B 367</td>
</tr>
<tr>
<td>Nickel cast iron (ductile nodular or graphitic)</td>
<td>A 436 Type 1</td>
</tr>
</tbody>
</table>

A Monel® or equivalent has been found satisfactory for this purpose.
B Hastelloy B or equivalent has been found satisfactory for this purpose.

6.3 Face Materials—Mechanical seal-wearing faces shall be selected to provide the desired performance and corrosion resistance for the specified design life of the seal.

6.3.1 Performance ranges for face combinations are listed in Table 2.

6.3.2 Face materials shall be of solid construction only; no overlays, deposited coatings, or sprayed on coatings are permitted.

6.3.3 Carbon is preferred for one of the faces unless the service is abrasive, dirty, or chemically active.

6.3.4 For special service requirements, hard on hard seal face combinations may be required. Face material combinations, such as silicon carbide versus silicon carbide, silicon carbide versus tungsten carbide, and tungsten carbide versus tungsten carbide, may be used as similar or dissimilar contacting face materials when recommended by the supplier and approved by the user.

6.4 Face Material Specifications:

6.4.1 Material—Suitable for service as recommended by the manufacturer. A carbon seal grade is a material having carbonaceous filler system comprised of pitch and resins, compacted and baked to a final temperature. These grades are subsequently impregnated with resin until they become impervious. All available carbons may not be suitable for a particular application. Carbons considered for use in a particular application shall be checked for suitability in accordance with the requirements of this specification.

6.4.2 Tungsten Carbide—6 to 10 % nickel or cobalt-bound solid tungsten carbide.

6.4.3 Ceramic—99.5 % minimum alumina ceramic suitable for the service as recommended by the manufacturer.

6.4.4 Silicon Carbide—(a) Reaction-Bonded—Solid fine-grained reaction-bonded silicon carbide 8 to 12 % free silicon, essentially free of carbon, impervious structure requiring no impregnant. (b) Reaction-Bonded With Graphite—A composite material of fine-grain reaction-bonded silicon carbide; 5 to 10 % free silicon and 10 to 30 % graphite; impervious structure requiring no impregnant. (c) Direct Sintered—Solid homogeneous silicon carbide essentially free of silicon and carbon, impervious structure requiring no impregnant. (d) Direct Sintered Silicon Carbide—Contains 10 % free graphite. (e) Silicocarbonized Carbon Graphite—Approximately 0.025-in. (0.64-mm) thick conversion of silicon carbide on carbon substructure and impregnated with thermosetting resin.

6.5 Elastomeric Materials:

6.5.1 Special care should be given to the selection and installation of elastomeric components, such as bellows and O-rings. One of the most important considerations for elastomers is fluid compatibility. Table 3 references most shipboard applications. Consult the seal manufacturer for fluids not listed.

6.5.2 Material Classification/Specification:

6.5.2.1 Nitrile—Practice D 1418, Class Designation NBR.
6.5.2.2 Chloroprene—Practice D 1418, Class Designation CR.
6.5.2.3 Fluorocarbon—Practice D 1418, Class Designation FKM.
FIG. 8 Stuffing Box Arrangement
6.5.2.4 Ethylene Propylene (EP)—Practice D 1418, Class Designation EPM/EPDM.

6.5.2.5 Perfluoroelastomer—Practice D 1418, Class Designation FFKM.

6.5.2.6 Polytetrafluorethylene (PTFE)—Specification D 3294.

6.5.2.7 Corrugated graphite ribbon packing.

6.5.3 Ethylene propylene (EP) rubber shall not be lubricated with any petroleum base substances. Check Section 11 and Appendix X1 or manufacturer’s recommendations before using any lubricant.

7. Performance Requirements

7.1 Seal life shall be defined in terms of the time period in which the mechanical seal functions properly under its specified service.

7.1.1 The minimum operational life of a mechanical seal shall be 16,000 statistical hours provided that the equipment is maintained and operated in accordance with the requirements of Section 8.
### TABLE 2 Seal Face Materials

<table>
<thead>
<tr>
<th>Seal Face Compatibility Chart</th>
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<tbody>
<tr>
<td>Primary Ring</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Siliconized carbon</td>
</tr>
<tr>
<td>Siliconized carbon</td>
</tr>
<tr>
<td>Silicon carbide</td>
</tr>
<tr>
<td>Silicon carbide</td>
</tr>
<tr>
<td>Tungsten carbide</td>
</tr>
</tbody>
</table>

$^{\mathrm{a}}$ Values of PV apply to aqueous solutions at 120°F (49°C). For lubricating liquids, such as oil, 60 % higher can be used. Given limits are to be used as a general guide in material selection. Values used consider a pressure drop across the seal faces as 0.5.

$^{\mathrm{b}}$ Limited to chemical service requirements only.

$^{\mathrm{c}}$ PV limit of 185 000 (6.57) can be used with two different grades of tungsten carbide, that is, cobalt versus nickel binders.

7.1.2 During any portion of the service life, the dynamic leakage shall not exceed five drops per minute for Class 0 seals. After initial installation, hydrostatic leakage shall be zero for a 5-min period, when the equipment is subjected to system pressure.

7.1.3 All split mechanical seals, Classes 1 through 4, may experience higher leakage rates than Class 0, solid mechanical seals. A leakage rate of five drops per minute shall be acceptable after completion of the manufacturer’s recommended break-in period.

7.1.4 In special applications of extreme environmental parameters, such as high temperature with limited cooling, high pressure/velocity, extreme abrasion, unusual equipment vibration, shaft end-play, or run-out, the pump and seal manufacturers shall agree upon the best achievable minimum operating life requirements and leakage performance.

7.1.5 Double or special seal arrangements may be required in applications in which zero product leakage to the environment is required such as hazardous fluids, fuel oil, acids, chemicals, and sewage. Consult the seal manufacturer for recommendations.

8. Design Requirements

8.1 Installation Arrangements:

8.1.1 Type A mechanical seals shall be provided unless otherwise specified.

8.1.2 Tandem or double mechanical seals may be installed in special applications in which it is determined that a buffer fluid system is required for lubrication, containment, or safety.

8.2 Finish and tolerance requirements for primary seal ring and mating ring surface flatness of Class 0 mechanical seals shall be three light bands or better as measured under a monochromatic, helium light source.

8.3 Requirements for Installation of Classes 1 Through 4 Split Mechanical Seals:

8.3.1 Classes 1 through 4, split mechanical seals, may be furnished for shaft/sleeve diameters of 1½ in. (38.1 mm) and above.

8.3.2 For split mechanical seal installations, a minimum of 3 in. (76.2 mm) of axial space, measured from the stuffing box face to the first obstruction, shall be provided for Classes 2 and 4 seals. Additional space, at least equal to the gland thickness, may be required for Classes 1 and 3 seals.

8.3.3 Classes 1 through 4, split mechanical seals, shall be designed to operate under a minimum reverse differential pressure condition of 15-in. Hg (50.8 kPa).

8.4 The requirement for a balanced or unbalanced seal will vary dependent upon the combination of various design and performance factors. Balanced seals shall normally be supplied for pressures greater than 150 psi (1.03 MPa) unless the seal manufacturer provides alternative recommendations for specific applications. Selection of a balanced or unbalanced seal design must satisfy the performance requirements of Section 7.

8.5 The mechanical seal shall be designed to operate satisfactorily under the following:

8.5.1 Shaft sleeve surface finish for pusher-type seals shall be 32 rms (0.80 µm) maximum. Shaft sleeve surface finish for nonpusher seals shall be 64 rms (1.60 µm) maximum.

8.5.2 Shaft radial run-out 0.010 in. (0.25 mm) TIR maximum.

8.5.3 Shaft end-play maximum ±0.015 in. (0.38 mm).

8.5.4 Concentricity of stuffing box bore to shaft axis 0.005 in. (0.13 mm) TIR maximum. Gland plate design must accommodate eccentricity stated herein.

8.5.5 Perpendicularity of stuffing box face to shaft axis 0.003 in. (0.08 mm) TIR maximum.

8.6 Environmental Controls—Environmental control considerations, such as flushing, cooling, heating, and quenching shall be specified by the seal manufacturer.


9.1 Quality Systems—Mechanical seals shall be supplied in accordance with ISO 9001.

9.2 Responsibility for Inspection—Unless otherwise specified, the manufacturer is responsible for the performance of all inspection requirements. The manufacturer may use his own or any other facilities suitable for inspection. The purchaser (buyer) reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

9.3 Material Inspection—The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with the specifications and standards as applicable.

9.4 Classification of Inspections—The inspection requirements specified herein shall be classified as follows:

9.4.1 Quality Conformance Inspection.

9.4.2 Inspection of Packaging.

9.5 Quality Conformance Inspection—All seal components shall be inspected in accordance with ASQC Z1.4 listing critical, major, and minor characteristics and type of inspection equipment used to determine said characteristics.

9.5.1 Acceptable Quality Level for Characteristics—The acceptable quality levels for characteristics, as per ASQC Z1.4, shall be as follows:

9.5.1.1 Critical—1.5 AQL
9.5.1.2 Major—2.5 AQL
9.5.1.3 Minor—4.0 AQL

9.5.2 Tests—All tests shall be performed in accordance with ASTM, ASME, or manufacturer’s standards as specified.

9.5.3 Test Data—All test data shall remain on file at the manufacturer’s facility for review by buyer upon request. It shall be retained in the manufacturer’s files for at least three years.

9.6 Inspection of Packaging:
9.6.1 Unit of Product—For the purpose of inspection, a completed package prepared for shipment shall be considered as a unit of product.

9.6.2 Sampling—Sampling for examination shall be in accordance with ASQC Z1.4. The AQL shall be 4.0 % defective.

9.6.3 Examination—Samples selected in accordance with 9.5.2 shall be examined for the following defects:

9.6.3.1 Materials, methods, container.
9.6.3.2 Strapping.
9.6.3.3 Consolidated seals not of like description.
9.6.3.4 Marking illegible, incorrect, incomplete, or missing.

9.7 Warranty:

9.7.1 Responsibility for Warranty—Unless otherwise specified, the manufacturer is responsible for the following:
9.7.1.1 All materials used to produce a unit.
9.7.1.2 Workmanship.
9.7.1.3 Manufacturer will warrant his product to be free from defect of workmanship.

9.8 Certification—When specified in the purchase order or contract, the purchaser (buyer) shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

10. Packing and Preparation for Delivery

10.1 Unit of Product—For the purpose of inspection, a completed package prepared for shipment shall be considered as a unit of product.

10.2 Packaging of Product for Delivery—Product should be packaged for shipment in accordance with standard industry practice.

10.3 Instructions—Instructions and manufacturer’s special provisions for handling shall be included in complete package.

10.3.1 Each of Classes 1 through 4, split mechanical seals, shall be supplied with detailed assembly and installation instructions.

10.3.2 All special or nonstandard tools and fixtures required to assemble and install the seal in the pump shall be identified and supplied with each seal package.

10.4 Any special packaging requirements for shipment or storage shall be identified in the ordering data. See Section 5.

10.5 Marking and Coding—When specified, a mechanical seal marking and coding system shall be used in accordance with Appendix X2.

11. Installation of the Seal Assembly

11.1 Seal suppliers shall provide instructions for each mechanical seal installation to include the applicable information required herein as a minimum.

11.2 Because of the variety of seal types and designs, Appendix X1 is provided for general guidance.

11.3 For specific detailed instructions, consult the seal supplier’s installation procedures. For reference to component identification terms, see Section 3 and Annex A1.
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established by the U.S. Navy, Commander Naval Sea Systems Command (NAVSEA), shall apply when specified in the contract or purchase order. When there is a conflict between the specifications and this Supplement S1, the requirements of Supplement S1 shall take precedence.

S1. Scope
S1.1 This supplementary requirement applies to mechanical end face seals for use in U.S. Navy shipboard pumps.
S1.2 Magnetic seals shall not be used.

S2. Referenced Documents
S2.1 ASTM Standards:
D 1141 Specification for Substitute Ocean Water
D 3951 Practice for Commercial Packaging
S2.2 Military Standards:5
MIL-S-901 Shock Tests, H.I. (High Impact); Shipboard Machinery, Equipment & Systems, Requirements for
MIL-P-16789 Packaging of Pumps, Including Prime Movers and Associated Repair Parts
MIL-R-83248 Rubber Fluorocarbon Elastomer, High Temperature, Fluid, and Compression Set Resistant
MS16142 Standard Dimensions for Gasket Seal Straight Thread Tube Fitting
MIL-STD-167-1 Environmental Vibration Testing

S3. Terminology:
S3.1 See Annex A1.

S4. Classification and Seal Arrangements:
S4.1 See Section 4.

S5. Design Requirements
S5.1 All mechanical seals shall meet the dimensional requirements from the applicable Tables S1-S4. Guidelines for seal/pump for S5 and S6 seals for cartridge and split mechanical seals are provided in Tables S5 and S6. Mechanical seals as shown in Table S1 Standard Long Mechanical Seals and Table S2 Standard Short Mechanical Seals, shall be of the single spring elastomeric bellows type. Slot details for antirotation pins applicable to Table S1 and Table S2 are shown in Fig. S1.
S5.2 Pusher type seals may be used for hydraulic oils, fuels, and lubricants.
S5.3 Mechanical seals to Tables S1-S4 shall be axially positioned or located on the shaft by positive means such as a stub, step, or shoulder on the shaft or a sleeve that is positively located on the shaft.
S5.4 Mechanical seals to Tables S1-S4 shall not be axially positioned by the use of set screws.
S5.5 Any special tools or spacers required to install and remove a mechanical seal shall be included with the seal.
S5.6 Mechanical seals supplied in accordance with Table S5 shall meet the following requirements:
S5.6.1 Table S5 mechanical seals may use setscrews to position the seal.
S5.6.2 A throttle bushing or secondary containment seal shall be used to limit leakage in event of seal failure. The diametrical clearance of the throttle bushing bore shall not be more than 0.025 in. for sleeve diameters up to 2.0 in. For larger diameters, the maximum diametrical clearance shall be 0.025 in. plus 0.005 in. for each additional 1.0 in. of diameter or fraction thereof. Mechanical seals used for lube oil and fuel services may use backup packing instead of throttle bushings.
S5.6.3 Non-sparking metallic assembly clips shall be used.
S5.6.4 Throttle bushing drain and seal flushing connections shall be provided with straight “O” ring fittings to MS 16142, minimum size ¼-in.
S5.7 Mechanical seals supplied in accordance with Table S6 shall meet the following requirements:
S5.7.1 No provision for back-up packing is required for split mechanical seals unless requested by the customer.
S5.7.2 Split mechanical seals shall not be used for fuel or lube oil service pumps.
S5.7.3 Mechanical seals supplied in accordance with Table S6 may leak at the seal faces during hydrostatic testing of the pump.
S5.8 Type E mechanical seals shall be the non-contacting design where the mating faces are designed to intentionally create aerodynamic or hydrodynamic separating forces to sustain a specific separation gap.
S5.8.1 Type E seals shall be used only on fuel/oil services with a shaft speed greater than 300 ft per min (fpm) measured at the shaft diameter.
S5.8.2 Nodular or graphitic ductile nickel cast iron mating rings allowed per Table S7 are not permitted in Type E seals.
S5.8.3 A self-contained gas seal support system (GSSS) shall be provided. The GSSS shall include check valve, gas regulator, pressure gage, and flowmeter. The GSSS components shall be enclosed in a box to protect from the elements. Flow and pressure indicators shall be visible from the outside of the box. GSSS shall be used to support the Type E seal during Section S7 testing. The GSSS shall undergo shock testing in accordance with MIL-S-901 and environmental vibration testing in accordance with MIL-STD-167-1.
S5.9 Unless otherwise specified, the seal manufacturer shall prepare drawings in accordance with ANSI Standards Y14.1, Y14.2, Y14.3, Y14.5, Y14.6, and Y14.26.3.
S5.9.1 Drawings shall be furnished under each contract or order unless the complete equipment covered by the drawings are identical in all respects to those previously submitted.
S5.9.2 Information intended for manufacturer’s use only shall be so designated.
S5.10 Drawings for each mechanical seal shall include a sectional assembly drawing and component detail drawings.
S5.10.1 Sectional assembly drawings shall include a sectional assembly with references to a parts list identifying materials for all individual parts.
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TABLE S1 Standard Long Mechanical Seal

NOTE 1—Standard (long) mechanical seal dimensions for Navy shipboard pump applications (low pressure, 150 psi (1.03 MPa) max, for new or
replacement applications).

A6
0.002

(A8) 6
0.05

B6
0.002

(B8) 6
−0.05

C
REF

(C8)
REF

D
min

(D8)
min

E
max

(E8)
max

L6
0.020

(L8) 6
−0.5

(M) 6
0.005

(M8) 6
0.12

(N) 6
0.15

(N8) 6
0.38

0.375
0.500
0.625
0.750
0.875
1.000
1.125
1.250
1.375
1.500
1.625
1.750
1.875
2.000
2.125
2.250
2.375
2.500
2.625
2.750
2.875
3.000
3.125
3.250
3.375
3.500
3.625
3.750
3.875
4.000

9.52
12.70
15.87
19.05
22.22
25.40
28.57
31.75
34.92
38.10
41.27
44.45
47.62
50.80
53.97
57.15
60.32
63.50
66.67
69.85
73.02
76.20
79.37
82.55
85.72
88.90
92.07
95.25
98.42
101.60

0.875
1.000
1.250
1.375
1.500
1.625
1.750
1.875
2.000
2.125
2.375
2.500
2.625
2.750
3.000
3.125
3.250
3.375
3.375
3.500
3.750
3.875
4.000
4.125
4.250
4.375
4.500
4.625
4.750
4.875

22.23
25.40
31.75
34.93
38.10
41.28
44.45
47.63
50.80
53.98
60.33
63.50
66.68
69.85
76.20
79.38
82.55
85.73
85.73
88.90
95.25
98.43
101.60
104.78
107.95
111.13
114.30
117.48
120.65
123.83

0.438
0.563
0.688
0.813
0.938
1.063
1.188
1.313
1.438
1.563
1.688
1.813
1.938
2.063
2.188
2.313
2.438
2.563
2.688
2.813
2.938
3.125
3.250
3.375
3.500
3.625
3.750
3.875
4.000
4.125

11.13
14.30
17.48
20.65
23.83
27.00
30.18
33.35
36.53
39.70
42.88
46.05
49.23
52.40
55.58
58.75
61.93
65.10
68.28
71.45
74.63
79.38
82.55
85.73
88.90
92.08
95.25
98.43
101.60
104.78

1.062
1.187
1.343
1.468
1.656
1.750
1.870
2.000
2.125
2.250
2.500
2.625
2.750
2.937
3.125
3.250
3.375
3.500
3.750
3.875
4.000
4.187
4.437
4.562
4.687
4.812
4.937
5.062
5.187
5.312

26.98
30.15
34.12
37.29
42.07
44.45
47.50
50.80
53.98
57.15
63.50
66.68
69.85
74.60
79.38
82.55
85.73
88.90
95.25
98.43
101.60
106.35
112.70
115.88
119.05
122.23
125.40
128.58
131.75
134.93

0.937
1.062
1.218
1.343
1.531
1.625
1.745
1.875
2.000
2.125
2.375
2.500
2.625
2.812
3.000
3.125
3.250
3.375
3.625
3.750
3.875
4.062
4.250
4.375
4.500
4.625
4.750
4.875
5.000
5.125

23.80
26.97
30.93
34.11
38.88
41.27
44.32
47.62
50.80
53.97
60.32
63.50
66.67
71.42
76.20
79.37
82.55
85.72
92.07
95.25
98.42
103.17
107.95
111.12
114.30
117.47
120.65
123.82
127.00
130.17

1.188
1.188
1.312
1.312
1.375
1.562
1.625
1.625
1.687
1.687
2.000
2.000
2.125
2.125
2.375
2.375
2.500
2.500
2.750
2.750
2.875
2.875
3.125
3.125
3.125
3.125
3.250
3.250
3.375
3.375

30.2
30.2
33.3
33.3
34.9
39.7
41.3
41.3
42.9
42.9
50.8
50.8
54.0
54.0
60.3
60.3
63.5
63.5
69.8
69.8
73.0
73.0
79.4
79.4
79.4
79.4
82.6
82.6
85.7
85.7

0.250
0.250
0.344
0.344
0.344
0.375
0.375
0.375
0.375
0.375
0.438
0.438
0.438
0.438
0.500
0.500
0.500
0.500
0.562
0.562
0.562
0.562
0.656
0.656
0.656
0.656
0.656
0.656
0.656
0.656

6.35
6.35
8.74
8.74
8.74
9.53
9.53
9.53
9.53
9.53
11.13
11.13
11.13
11.13
12.70
12.70
12.70
12.70
14.30
14.30
14.30
14.30
16.66
16.66
16.66
16.66
16.66
16.66
16.66
16.66

0.312
0.312
0.406
0.406
0.406
0.438
0.438
0.438
0.438
0.438
0.500
0.500
0.500
0.500
0.562
0.562
0.562
0.562
0.625
0.625
0.625
0.625
0.781
0.781
0.781
0.781
0.781
0.781
0.781
0.781

7.92
7.92
10.31
10.31
10.31
11.13
11.13
11.13
11.13
11.13
12.70
12.70
12.70
12.70
14.27
14.27
14.27
14.27
15.87
15.87
15.87
15.87
19.84
19.84
19.84
19.84
19.84
19.84
19.84
19.84

Notes:
A to N = English units. A8 to N8 = SI (metric) units.
I)
For mating ring antirotation slot detail see Fig. S1
II) B—Gland counterbore
C—Min shaft clearance bore recommended tolerance + 0.030 (0.076)/-0.000
D—Min stuffing box bore
E—Max seal O.D. (within stuffing box)

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TABLE S2 Standard Short Mechanical Seal

NOTE 1—Standard (short length), mechanical seal dimensions for Navy shipboard pump applications (low pressure, 150 psi (1.03 MPa) max, for new
or replacement applications).

A6
0.002

(A8) 6
0.05

B6
0.002

(B8) 6
−0.05

C
REF

(C8)
REF

D
min

(D8)
min

E
max

(E8)
max

L6
0.020

(L8) 6
−0.5

(M) 6
0.005

(M8) 6
0.12

(N) 6
0.15

(N8) 6
0.38

0.375
0.500
0.625
0.750
0.875
1.000
1.125
1.250
1.375
1.500
1.625
1.750
1.875
2.000
2.125
2.250
2.375
2.500
2.625
2.750
2.875
3.000
3.125
3.250
3.375
3.500
3.625
3.750
3.875
4.000

9.52
12.70
15.87
19.05
22.22
25.40
28.57
31.75
34.92
38.10
41.27
44.45
47.62
50.80
53.97
57.15
60.32
63.50
66.67
69.85
73.02
76.20
79.37
82.55
85.72
88.90
92.07
95.25
98.42
101.60

0.875
1.000
1.250
1.375
1.500
1.625
1.750
1.875
2.000
2.125
2.375
2.500
2.625
2.750
3.000
3.125
3.250
3.375
3.375
3.500
3.750
3.875
4.000
4.125
4.250
4.375
4.500
4.625
4.750
4.875

22.23
25.40
31.75
34.93
38.10
41.28
44.45
47.63
50.80
53.98
60.33
63.50
66.68
69.85
76.20
79.38
82.55
85.73
85.73
88.90
95.25
98.43
101.60
104.78
107.95
111.13
114.30
117.48
120.65
123.83

0.438
0.563
0.688
0.813
0.938
1.063
1.188
1.313
1.438
1.563
1.688
1.813
1.938
2.063
2.188
2.313
2.438
2.563
2.688
2.813
2.938
3.125
3.250
3.375
3.500
3.625
3.750
3.875
4.000
4.125

11.13
14.30
17.48
20.65
23.83
27.00
30.18
33.35
36.53
39.70
42.88
46.05
49.23
52.40
55.58
58.75
61.93
65.10
68.28
71.45
74.63
79.38
82.55
85.73
88.90
92.08
95.25
98.43
101.60
104.78

1.218
1.375
1.562
1.687
1.812
2.000
2.125
2.250
2.437
2.562
2.937
3.062
3.187
3.312
3.625
3.750
3.875
4.000
4.312
4.437
4.562
4.687
5.000
5.125
5.250
5.500
5.687
5.812
6.000
6.125

30.94
34.93
39.68
42.85
46.03
50.80
53.98
57.15
61.90
65.08
74.60
77.78
80.95
84.13
92.08
95.25
98.43
101.60
109.53
112.70
115.88
119.05
127.00
130.18
133.35
139.70
144.45
147.63
152.40
155.58

1.031
1.187
1.375
1.500
1.625
1.812
1.937
2.062
2.250
2.375
2.718
2.750
2.875
3.000
3.250
3.375
3.500
3.625
3.875
4.000
4.125
4.250
4.562
4.687
4.812
4.937
5.125
5.250
5.437
5.562

26.18
30.15
34.92
38.10
41.27
46.02
49.20
52.37
57.15
60.32
69.03
69.85
73.02
76.20
82.55
85.72
88.90
92.07
98.42
101.60
104.77
107.95
115.87
119.05
122.22
125.40
130.17
133.35
138.10
141.27

0.812
0.812
0.875
0.875
0.937
1.000
1.062
1.062
1.125
1.125
1.375
1.375
1.500
1.500
1.687
1.687
1.812
1.812
1.937
1.937
2.062
2.062
2.187
2.187
2.187
2.187
2.312
2.312
2.437
2.437

20.7
20.7
22.7
22.7
23.8
25.4
27.0
27.0
28.6
28.6
34.9
34.9
38.1
38.1
42.9
42.9
46.0
46.0
49.2
49.2
52.4
52.4
55.6
55.6
55.6
55.6
58.8
58.8
61.9
61.9

0.250
0.250
0.344
0.344
0.344
0.375
0.375
0.375
0.375
0.375
0.438
0.438
0.438
0.438
0.500
0.500
0.500
0.500
0.562
0.562
0.562
0.562
0.656
0.656
0.656
0.656
0.656
0.656
0.656
0.656

6.35
6.35
8.74
8.74
8.74
9.53
9.53
9.53
9.53
9.53
11.13
11.13
11.13
11.13
12.70
12.70
12.70
12.70
14.30
14.30
14.30
14.30
16.66
16.66
16.66
16.66
16.66
16.66
16.66
16.66

0.312
0.312
0.406
0.406
0.406
0.438
0.438
0.438
0.438
0.438
0.500
0.500
0.500
0.500
0.562
0.562
0.562
0.562
0.625
0.625
0.625
0.625
0.781
0.781
0.781
0.781
0.781
0.781
0.781
0.781

7.92
7.92
10.31
10.31
10.31
11.13
11.13
11.13
11.13
11.13
12.70
12.70
12.70
12.70
14.27
14.27
14.27
14.27
15.87
15.87
15.87
15.87
19.84
19.84
19.84
19.84
19.84
19.84
19.84
19.84

Notes:
A to N = English units. A8 to N8 = SI (metric) units.
I)
For mating ring antirotation slot detail see Fig. S1
II) B—Gland counterbore
C—Min shaft clearance bore recommended tolerance + 0.030 (0.076)/-0.000
D—Min stuffing box bore
E—Max seal O.D. (within stuffing box)

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TABLE S3 Special Cartridge Seals Grade 2

<table>
<thead>
<tr>
<th>A ±</th>
<th>(A') ±</th>
<th>B ±</th>
<th>(B') ±</th>
<th>C</th>
<th>(C')</th>
<th>D</th>
<th>(D')</th>
<th>E</th>
<th>(E')</th>
<th>F</th>
<th>(F')</th>
<th>G</th>
<th>(G')</th>
<th>H</th>
<th>(H')</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002</td>
<td>0.05</td>
<td>0.002</td>
<td>0.05</td>
<td>Ref</td>
<td>Ref</td>
<td>min</td>
<td>min</td>
<td>max</td>
<td>max</td>
<td>min</td>
<td>min</td>
<td>min</td>
<td>min</td>
<td>max</td>
<td>max</td>
</tr>
<tr>
<td>1.186</td>
<td>30.12</td>
<td>3.066</td>
<td>77.88</td>
<td>2.726</td>
<td>69.24</td>
<td>2.44</td>
<td>61.98</td>
<td>2.348</td>
<td>59.64</td>
<td>1.29</td>
<td>32.77</td>
<td>0.19</td>
<td>4.83</td>
<td>0.50</td>
<td>12.70</td>
</tr>
<tr>
<td>1.377</td>
<td>34.98</td>
<td>3.066</td>
<td>77.88</td>
<td>2.726</td>
<td>69.24</td>
<td>2.44</td>
<td>61.98</td>
<td>2.420</td>
<td>61.47</td>
<td>1.51</td>
<td>38.35</td>
<td>0.31</td>
<td>7.87</td>
<td>0.50</td>
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</tr>
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<td>36.47</td>
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<td>3.416</td>
<td>86.77</td>
<td>2.94</td>
<td>74.68</td>
<td>2.763</td>
<td>70.18</td>
<td>1.54</td>
<td>39.12</td>
<td>0.19</td>
<td>4.83</td>
<td>0.62</td>
<td>15.75</td>
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<tr>
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<td>98.48</td>
<td>3.416</td>
<td>86.77</td>
<td>2.94</td>
<td>74.68</td>
<td>2.861</td>
<td>72.67</td>
<td>2.00</td>
<td>50.80</td>
<td>0.12</td>
<td>3.05</td>
<td>0.62</td>
<td>15.75</td>
</tr>
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</table>

Notes:
A to R = English units. A' to R' = SI (metric) units.
B—Gland counterbore
C—Seal support shoulder tolerance + 0.030 (0.76)/−0.000
D—Minimum stuffing box bore
E—Maximum seal O.D. (within stuffing box)
F—Positive drive recess for seal assembly drive lug, 2 each 180° apart
G—Positive drive recess for seal assembly drive lug, 2 each 180° apart
H—Maximum pin length shown, max pin diameter 0.125
J—Positive drive recess for stationary seal ring
K—Clearance required between seal and seal locating shoulder
R—Four lugs equally spaced at 90°
### TABLE S4  Special Cartridge Seals Grade 1

#### Notes:
- **A** to **S** = English units. **A’** to **S’** = SI (metric) units.
- **B**—Gland counterbore
- **C**—Seal support shoulder tolerance + 0.030 (0.76)/−0.000
- **D**—Minimum stuffing box bore
- **E**—Maximum seal O.D. (within stuffing box)
- **F**—Positive drive recess for seal assembly drive lug. 2 each 180° apart
- **G**—Positive drive recess for seal assembly drive lug. 2 each 180° apart
- **H**—Maximum pin length shown, max pin diameter 0.125
- **J**—Positive drive recess for stationary seal ring
- **K**—Clearance required between seal and seal locating shoulder 2 each 180° apart
- **R**—One recess only
- **N/A**—Not applicable

<table>
<thead>
<tr>
<th>A ±</th>
<th>(A') ±</th>
<th>B ±</th>
<th>(B') ±</th>
<th>C</th>
<th>(C')</th>
<th>D</th>
<th>(D')</th>
<th>E</th>
<th>(E')</th>
<th>E</th>
<th>(E')</th>
<th>G</th>
<th>(G')</th>
<th>H</th>
<th>(H')</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002</td>
<td>0.05</td>
<td>0.002</td>
<td>0.05</td>
<td></td>
<td>Ref</td>
<td>min</td>
<td>min</td>
<td>max</td>
<td>max</td>
<td>min</td>
<td>min</td>
<td>min</td>
<td>min</td>
<td>max</td>
<td>max</td>
</tr>
<tr>
<td>0.811</td>
<td>20.60</td>
<td>1.851</td>
<td>47.02</td>
<td>1.605</td>
<td>40.77</td>
<td>1.67</td>
<td>42.42</td>
<td>1.583</td>
<td>40.21</td>
<td>0.94</td>
<td>23.88</td>
<td>0.12</td>
<td>3.02</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>1.000</td>
<td>25.40</td>
<td>1.877</td>
<td>47.68</td>
<td>1.100</td>
<td>27.94</td>
<td>2.09</td>
<td>53.09</td>
<td>2.011</td>
<td>51.08</td>
<td>1.10</td>
<td>27.94</td>
<td>0.09</td>
<td>2.29</td>
<td>0.13</td>
<td>3.30</td>
</tr>
<tr>
<td>1.876</td>
<td>47.65</td>
<td>2.752</td>
<td>69.90</td>
<td>2.100</td>
<td>53.34</td>
<td>3.36</td>
<td>85.34</td>
<td>3.315</td>
<td>84.20</td>
<td>2.00</td>
<td>50.80</td>
<td>0.21</td>
<td>5.33</td>
<td>0.18</td>
<td>4.57</td>
</tr>
<tr>
<td>2.162</td>
<td>54.91</td>
<td>3.127</td>
<td>79.43</td>
<td>2.218</td>
<td>56.34</td>
<td>3.60</td>
<td>91.44</td>
<td>3.252</td>
<td>82.60</td>
<td>2.38</td>
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**View for 0.811(20.60) Shaft Size Only**
### TABLE S5 Cartridge Seal

**Maximum Dimensions for Seal Installation**

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## TABLE S6  Split Mechanical Seals

**Maximum Dimensions for Seal Interface**

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<th>D Outboard Space Required (in.)</th>
<th>E Nearest Obstruction (in.)</th>
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<td>5.75</td>
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<td>4.02</td>
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<td>5.12</td>
<td>5.75</td>
<td>0.407</td>
<td>2.53</td>
<td>4.02</td>
<td>9.00</td>
<td>6.56</td>
<td>.68</td>
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<td>0.457</td>
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<td>9.55</td>
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<td>4.02</td>
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<td>.75</td>
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<td>0.432</td>
<td>2.50</td>
<td>4.02</td>
<td>9.77</td>
<td>7.38</td>
<td>.75</td>
<td>7.50</td>
<td>.75</td>
<td>7.63</td>
<td>.75</td>
</tr>
</tbody>
</table>
S5.10.1.1 All running clearances shall be shown and shall be dimensioned and labeled as diametral clearances.
S5.10.1.2 Tightening torques with tolerances and thread lubrication requirements for threaded fasteners shall be shown on the drawing.
S5.10.1.3 Assembly drawings shall show, as a minimum, the dimensions shown on the applicable Tables S1-S4.
S5.10.1.4 Drawings shall specify the type, amount, and required use of lubricant.
S5.10.1.5 Drawings shall specify where there is an adhesive or other setting compound factory installed on the elastomer bellows or O-ring that seals between the mechanical seal and the impeller hub, shaft, or shaft sleeve.
S5.10.1.6 Drawings shall provide a description of any adhesive or setting compound identified in S5.10.1.5 including any time limits associated with the compound when present on a mechanical seal in storage and between initial wetting of that compound and the final positioning of the mechanical seal in the pump.
S5.10.2 When requesting qualification testing to satisfy Tables S1—S6, component drawings shall be submitted to NAVSEA for review and approval. Drawings to include dimensional details, manufacturing tolerances, and material specifications. Seal drawings to be used for NAVSEA verification only.
S5.10.3 Shock requirements are specified under Section S7.8 Shock Test.

S5.11 "J-seat" stationary ring designs shall be allowed for lube oil and fuel oil services.

S6. Materials

S6.1 The mechanical seal metal parts shall be supplied in accordance with Table S5.
S6.2 The primary seal ring shall be carbon-graphite, silicon carbide, or 6 to 10 % nickel-bound tungsten carbide. The mating ring face shall be 6 to 10 % nickel-bound tungsten carbide or silicon carbide and suitable for the liquid being pumped. Cobalt-bound tungsten carbide shall not be used. Nodular or graphitic ductile nickel cast iron may be supplied for lubricants and fuel oil service.
S6.3 Elastomers such as bellows, O-rings, friction rings, and so forth, furnished with seals supplied to the requirements of this Supplement S1 shall be made of fluorocarbon elastomer in accordance with MIL-R-83248, CL 1 or Cl 2, or Practice CTI–6 or P8412.
Alternative carbon graphite materials will be conditionally approved by NAVSEA for specific mechanical seal service. Approval for general service will be granted after seal qualification testing under this specification and after evidence of satisfactory shipboard service under equivalent operating conditions, is provided.

| FIG. S1 Dimensional Record |

<table>
<thead>
<tr>
<th>Mating Ring Wear</th>
<th>Primary Seal Wear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours of Runtine</td>
<td>Wear Rate Inch/hr</td>
</tr>
</tbody>
</table>

Pr 2

Wear Rate × Hours of Seal Life

---

6 Carbon graphite material shall be a manufacturer’s grade that has been tested and qualified for mechanical seal face service under the qualification tests required by this specification and has been documented as being in regular shipboard service under equivalent operating conditions.
S6 Split Seals shall use carbon graphite grades CTI–6 or P8412.
Alternative carbon graphite materials will be conditionally approved by NAVSEA for specific mechanical seal service. Approval for general service will be granted after seal qualification testing under this specification and after evidence of satisfactory shipboard service under equivalent operating conditions, is provided.
7 Ni-Resist or equivalent has been found satisfactory for this purpose.
D 1418 Class FKM, unless otherwise specified in the contract. Refer to Table 3 for general service applications and for alternative elastomers suitable for special requirements.

S6.4 On seawater pumps, the mechanical seal O-rings and other elastomers shall not be mounted on or come in contact with the impeller.
S6.5 All mechanical seals under this specification shall be certified to be free of functional mercury.

S7. Testing of Mechanical Seals

S7.1 The purpose of these test procedures is to develop a high confidence level that a Class 0 mechanical seal has a projected statistical life of 16,000 h under normal field service conditions.

S7.2 To qualify a mechanical seal design, NAVSEA\(^8\) will first conduct a technical evaluation, reviewing the manufacturer’s design for compliance with this specification, configuration, material and performance requirements. Subsequent to technical evaluation, the seal will undergo a performance evaluation, including:

(a) Technical evaluation, including:

\(6.5\)  The technical evaluation will include the following:

- Material and performance requirements.
- Subsequent to technical evaluation, the seal will undergo a performance evaluation, including:

- Test parameters monitored/measured:

<table>
<thead>
<tr>
<th>Parameters Monitored/Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating pressure</td>
</tr>
<tr>
<td>Operating temperature</td>
</tr>
<tr>
<td>Surface speed (ft/min)</td>
</tr>
<tr>
<td>Fluid media</td>
</tr>
<tr>
<td>Leakage rate</td>
</tr>
<tr>
<td>Wear rate</td>
</tr>
</tbody>
</table>

- S7.2.2 Run-In Test:

<table>
<thead>
<tr>
<th>Test</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-in—8 h</td>
<td></td>
</tr>
<tr>
<td>Hydrostatic—5 min</td>
<td></td>
</tr>
<tr>
<td>Operational—500 h</td>
<td></td>
</tr>
<tr>
<td>Shock—Mil-S-901 (Grade A)</td>
<td></td>
</tr>
</tbody>
</table>

- S7.2.2.1 Testing, including qualification testing, of Classes 1 through 4 split mechanical seals shall be application specific, conducted under test conditions, which include the proposed operating conditions, and under a test schedule and performance requirements that have been agreed upon by the purchaser (buyer) and the manufacturer.

- S7.2.2.2 Type E seals shall be tested with 0.035 in. of axial endplay towards the driver end of the pump.

- S7.2.2.3 The 500 h endurance test for Type E seals shall be accomplished using a fluid with a viscosity of 100-500 SSU at start-up. Air shall be used as the barrier fluid.

- S7.2.2.4 Run-In Test:

<table>
<thead>
<tr>
<th>Test</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-in—8 h</td>
<td></td>
</tr>
<tr>
<td>Hydrostatic—5 min</td>
<td></td>
</tr>
<tr>
<td>Operational—500 h</td>
<td></td>
</tr>
<tr>
<td>Shock—Mil-S-901 (Grade A)</td>
<td></td>
</tr>
</tbody>
</table>

- Parameters Monitored/Measured:

<table>
<thead>
<tr>
<th>Parameters Monitored/Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating pressure</td>
</tr>
<tr>
<td>Operating temperature</td>
</tr>
<tr>
<td>Surface speed (ft/min)</td>
</tr>
<tr>
<td>Fluid media</td>
</tr>
<tr>
<td>Leakage rate</td>
</tr>
<tr>
<td>Wear rate</td>
</tr>
</tbody>
</table>

- S7.2.2.4 Type E seals shall undergo a seal recovery test. Test shall be performed in the following order:

1. 15 min at 300 fpm, 65 psig fluid pressure, 125 psig barrier pressure
2. 15 min at 300 fpm, 65 psig fluid pressure, disconnect air source, vent to atmosphere
3. 15 min at 800 fpm, 100 psig fluid pressure, 125 psig barrier pressure
4. 15 min at 800 fpm, 100 psig fluid pressure, disconnect air source, vent to atmosphere
5. 15 min at 300 fpm, 65 psig fluid pressure, 125 psig barrier pressure

At the end of the recovery test, there shall be no visible fluid leakage. Maximum barrier consumption rate shall be 0.47 nl/min or 1.0 scfh.

- S7.2.3 Any changes to a qualified mechanical seal shall be presented to the government buying activity for technical evaluation.

- S7.3 General Comments:

- S7.3.1 Data will be collected and entered on data sheets similar to those in Fig. S1 and Fig. S2.

- S7.3.2 Any problems encountered with the seals, installation, operation of the test fixture, or breakdowns of any kind, shall be recorded. This record shall include a statement of the problem, cause, running time meter reading at occurrence, and any other pertinent information.

- S7.3.3 All tests shall be performed in sea water using the same seal.

- S7.3.4 The test conditions shall be:

<table>
<thead>
<tr>
<th>Speed</th>
<th>Tables S1 and S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3600 rpm</td>
<td>±5 %</td>
</tr>
<tr>
<td>1800 rpm</td>
<td>±5 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tables S3 and S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>170°F (77°C)</td>
<td>Monitor seal cavity, flowrate be varied as necessary to maintain at seal cavity at specified temperature.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pressure (1.03 MPa)</th>
<th>±5 psi (0.03 MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 psig</td>
<td></td>
</tr>
</tbody>
</table>

Fluid media: ocean water per Specification D 1141

- S7.3.5 Any seal shown in Table S1 and Table S2 successfully passing all tests will qualify any smaller seal of the same design up to but not including 1 in. (25.4 mm) smaller.\(^9\)

- S7.3.6 Test Facility—The test facility must be approved by NAVSEA\(^8\) before conducting the tests. Approval criteria will be based on information submitted by the facility demonstrating the capability to perform all tests indicated herein.

- S7.4 Pretest Inspection:

- S7.4.1 The seal shall be photographed as received from the manufacturer and examined for compliance. The mating surfaces shall be photographed to document the original unworn condition. All critical dimensions shall be measured and recorded. The width of the stationary mating ring and the height of the rotating primary seal nose shall be measured at 60° intervals. A reference point for these measurements shall be established to ensure that the posttest measurements are taken at identical locations. If a seal face is not measurable as an individual component, the manufacturer must provide the

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\(^8\) Department of the Navy, Naval Sea Systems Command, NAVSEA, Arlington, VA 22242-5160.

\(^9\) Example: Successfully qualifying a 2.000-in. (50.8-mm) diameter seal would likewise qualify all seal sizes from 2.000 to 1.125 in. (50.8 to 28.5 mm).
information with photographs and certify the critical dimensions to 0.0001 in. (2.5 mm). Acceptance criteria: seal face wear rate must allow for an extrapolated service life of 16 000 h.

S7.4.2 The seal shall be examined for the following defects:
S7.4.2.1 Components missing or not as specified.
S7.4.2.2 Dimensions not as specified.
S7.4.2.3 Materials not as specified.
S7.4.2.4 Assembly incorrect.
S7.4.2.5 Workmanship not as specified.
S7.4.2.6 Configuration not in conformance with drawing.

S7.5 Run-In Test—After completion of the pretest inspection and seal installation, the test fixture shall be stabilized at the temperature, pressure, and speed specified for the test which shall be conducted immediately after the run-in test. The seal shall be operated for a period of 8 h continuously at test conditions and stopped. All the area on the test fixture that would collect fluid escaping past the seal shall be wiped clean.

FIG. S2 Mechanical Seal Test Data Sheet
and dry. The seal shall then be operated at the same test conditions for 20 min after which the leakage will be checked. Acceptance criteria: there shall be no apparent leakage.

S7.6 Hydrostatic Test—After successful completion of the prerequisites specified in the previous sections, the seal shall be subjected to 1.5 times the operational test pressure for a period of 5 min. During this test, the motor shall not be operated. Acceptance criteria: there shall be no measurable leakage.

S7.7 Operational Test:
S7.7.1 After successful completion of the hydrostatic test, the seal shall remain in the test fixture for the purpose of conducting the operational test.
S7.7.2 The seal test fixture shall be stabilized at the temperature, pressure, and speed specified. The operational test shall be for a period of 500 h running time with a minimum of 25 starts. Testing will be conducted at the neutral position and with axial and radial offsets, for the duration of the test sequences as listed in Table S6.
S7.7.3 During the operational test, the test fixture shall be monitored to record accurately the conditions of operation (pressure, temperature, speed, and so forth). Data shall be collected and the fixture examined at least twice daily. In addition to all measured data, the record shall indicate the seal leakage rate. Acceptance criteria: (1) There shall be no measurable leakage. (2) Seal face wear rate extrapolates to a minimum service life of 16 000 h.

S7.8 Shock Test:
S7.8.1 The governing document for the shock test shall be MIL-S-901. The seal test fixture, mounted on the anvil plate of a shock testing machine for lightweight equipment, shall be tested with water and shall be stabilized at room temperature, 30 psig (207 kPa) and 1800 or 3600 rpm. General requirements for the shock test are as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Class</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

All mounting and testing shall be performed in accordance with the requirements of MIL-S-901 pertaining to lightweight shock. Shock tests shall be conducted in the dynamic mode of operation. Seal leakage rate shall be monitored and recorded. Acceptance criteria: mechanical seal leakage rate shall not exceed five drops/min.
S7.8.2 A mechanical seal may also be qualified by testing in a pump unit as per MIL-S-901.

S7.9 Posttest Inspection—After completion of tests specified in S7.1 to S7.6, the seal shall be removed and all seal components closely examined. Record any unusual details. After removal, the seal shall be disassembled and an internal examination of the seal conducted as specified in S7.2.1. Wear shall be measured at 60° intervals relative to the reference point established during the pretest inspection. Photographs shall be used to document the worn condition of the seal. Average wear rate for the operational test shall be extrapolated to 16 000 h to determine the service life wear requirement. Examine and analyze the data obtained above and compare it to the data collected during the pretest inspection.

S8. Packaging and Marking
S8.1 The packaging and marking requirements specified herein apply only for direct U.S. Government acquisitions.
S8.2 Mechanical seals shall be preserved-packaged level A or C, packed level A, B, or C as specified, and marked in accordance with MIL-P-16789. Unless otherwise specified, package in accordance with Practice D 3951.

ANNEX

(Mandatory Information)

A1. TERMINOLOGY: DESCRIPTION OF TERMS RELATING TO MECHANICAL SEALS AND THEIR APPLICATION

A1.1 balanced seal—a mechanical seal designed to accommodate high stuffing box pressure with a decrease in seal face closing forces.
A1.2 barrier fluid—see buffer fluid.
A1.3 bellows—flexing seal elements:
A1.3.1 An elastomeric seal element with a full or half convolution that acts as a flexible secondary seal.
A1.3.2 Formed or welded metal seal element that provides spring load and a flexible secondary seal. See Fig. 1 and Fig. 4.
A1.4 buffer fluid—a lubricating liquid which is introduced between two seal assemblies to provide protection to the seal and/or the environment.
A1.5 bushing—a device used to restrict flow. See Fig. 1.
A1.6 cartridge seal—a completely self-contained assembly including seal, gland, sleeve, and drive collar or seal assembly & which can be assembled on to a pump as one unit.
A1.7 centrifugal separator—a device using centrifugal force to remove solids in a seal flushing liquid.
A1.8 diametral clearance—the difference between the diameters of two parts.
A1.9 double seal—two mechanical seals mounted back to back, or face to face, designed to contain a buffer fluid between the two seals. See Figs. 4-6.
A1.10 elastomer drive seal—a mechanical seal in which rotation of the seal assembly is accomplished through an elastomeric secondary seal.
A1.11 *end play*—movement along the axis or parallel to the center line of a shaft.

A1.12 *end face seal*—a mechanical seal that prevents leakage of fluids. Sealing is accomplished by means of a stationary seal ring bearing against the face of a rotating ring mounted on a shaft. Primary sealing is accomplished in a plane perpendicular to the shaft axis.

A1.13 *flush*—liquid that is introduced into the seal chamber in close proximity to the sealing faces.

A1.14 *gland gasket*—a static seal used between the gland plate and the pump casing.

A1.15 *gland plate*—a pressure-containing housing that is attached to the pump casing and holds the stationary part of the seal.

A1.16 *gland plate, solid*—a gland plate, according to A1.15, whose pressure retaining member is not radially split.

A1.17 *gland plate, split*—a gland plate that is split on a plane parallel to the axis of the shaft, with the result that the gland can be assembled around the shaft without requiring access over the end of the shaft.

A1.18 *inside mounted seal*—a mechanical seal assembly mounted inside the cavity which holds the fluid to be sealed.

A1.19 *light bands*—the horizontal distance between corresponding dark fringes on a reflective objective reference when viewed through an optical flat exposed to a monochromatic light source. For flatness measurement, the distance from one dark fringe to the next is 11.566 µin. for a helium gas light.

A1.20 *mating ring*—a precision lapped seal face normally mounted in a gland plate.

A1.21 *noncontacting seal*—a seal where the mating faces are designed to intentionally create an aerodynamic or hydrodynamic separating force to sustain a separation gap.

A1.22 *nonpusher seal*—a mechanical seal in which seal wear and end-play are compensated for by flexing a secondary seal element.

A1.23 *operating length*—the axial distance from the seal face to a reference plane. Also referred to as seal working height.

A1.24 *outside mounted seal*—a mechanical seal assembly mounted outside the cavity which holds the fluid to be sealed.

A1.25 *packing*—materials fitted into a stuffing box and compressed to form a seal between the shaft and the stuffing box bore.

A1.26 *positive drive*—mechanical means of providing rotational torque in a rotating seal element or preventing rotation in a stationary seal element by use of pins, tabs, keys, or set screws.

A1.27 *primary seal ring*—a precision lapped seal face which is held in the seal assembly.

A1.28 *pumping ring*—a simplified impeller within the seal cavity which circulates liquid for cooling.

A1.29 *pusher seal*—a mechanical seal with a dynamic secondary seal element.

A1.30 *quench*—a fluid that is introduced on the atmospheric side of the seal. Quench fluid is introduced through ports in the gland plate.

A1.31 *rotating seal*—a seal assembly in which the primary spring mechanism is rotated with the shaft.

A1.32 *seal cavity*—the space within a pump housing or gland between a stuffing box bore and a shaft in which a seal is installed.

A1.33 *seal nose*—the axial projection on the primary seal ring of an end face seal which forms the sealing surface.

A1.34 *secondary seal*—a device which provides dynamic sealing between the rotating element of a mechanical seal assembly and the shaft or sleeve. See Figs. 1 and 6.

A1.35 *shaft run-out*—twice the distance by which the center of the shaft is displaced from the axis of rotation.

A1.36 *shaft sleeve*—a cylinder placed over a shaft to provide protection of the shaft from wear and corrosion. It may be used to provide spacing for the impeller and as a device to provide a step in the shaft to achieve seal balance and/or positioning.

A1.37 *sleeve gasket*—a static seal used to prevent leakage between the shaft and the sleeve.

A1.38 *split seal*—a mechanical seal that has its elements split in a plane parallel to the axis of the shaft, with the result that instead of being continuous rings, they are essentially two semicircles.

A1.39 *split seal, partial*—a split mechanical seal in which only the rotating and stationary sealing face components and packing elements are split and replaceable by assembly around the shaft.

A1.40 *split seal, fully*—a split mechanical seal in which all of the rotating and stationary seal components are split, allowing the entire seal to be assembled around the shaft without requiring access over the end of the shaft.

A1.41 *static seal*—a seal between surfaces which have no relative motion.

A1.42 *stationary seal*—a seal assembly in which the primary spring mechanism does not rotate.

A1.43 *stuffing box pressure*—operating pressure for the mechanical seal.
A1.44 **tandem seal**—a multiple seal arrangement consisting of two seals mounted one after the other, with the faces of the seal assemblies oriented in the same direction. See Fig. 6.

A1.45 **throat bushing**—a bushing mounted at the bottom of the stuffing box that restricts flow into or out of the seal cavity. (See bushing.)

A1.46 **throttle bushing**—a bushing mounted in the gland to restrict flow of seal leakage or quench fluid to atmosphere. (See bushing.)

A1.47 **unbalanced seal**—a seal in which the total hydraulic pressure in the seal cavity acts on the faces of the mechanical seal.

**APPENDIXES**

*(Nonmandatory Information)*

**X1. SEAL ASSEMBLY INSTALLATION INSTRUCTIONS**

**X1.1 Before Installation of Seal:**

X1.1.1 Review the seal manufacturer’s installation drawings or instructions, or both.

X1.1.2 Verify proper equipment interface requirements as per 8.3.

X1.1.3 Keep the seal assembly clean and protected, especially the faces. If faces contain protective covering, leave the covering on until the last possible moment. If the rotary or stationary units must be touched, always cover the faces with a clean dry cloth.

X1.1.4 Check the secondary seals. Certain types require special lubricants or preparation before the placement in the equipment. PTFE wedges, V-, O-rings, and TFE-encapsulated O-rings may require special treatment before placement on shaft or in groove.

X1.2 **Seal Assembly Installation Procedures**—For cartridge or split seal designs, consult specific manufacturer’s installation instructions.

X1.2.1 Remove any loose matter in stuffing box and stationary cavity in gland plate with a cloth. Wipe these areas clean.

X1.2.2 Remove all burrs and sharp edges on shaft.

X1.2.3 Wipe shaft clean with a dry clean cloth.

X1.2.4 Lubricate the shaft and secondary seal.

X1.2.5 Elastomeric driven seals require the shaft to be lubricated with water or a very light grade oil. A nongranulated waterless soap is recommended. (Warning—Do not use petroleum jelly, TFE (tetrafluoroethylene), or silicone grease on an elastomer driven seal. EPR (ethylene propylene rubber) must not be lubricated with any petroleum base substance.)

X1.3 **Installing the Mating Ring:**

X1.3.1 Check to make sure that the cavity for the mating ring is clean and free of all foreign matter.

X1.3.2 Lubricate the mating ring static seal as in Paragraph X1.2.5.

X1.3.3 Carefully install mating ring by pressing it into the gland plate counterbore until it is bottomed and square.

X1.4 **Installation of the Seal and Mating Ring Assembly:**

X1.4.1 Slide the seal assembly on to the pump shaft. Make certain that it is properly positioned in relationship to the stuffing box and shaft. If set screws are used, verify installation reference to face of stuffing box. Tighten set screws.

X1.4.2 Before setting the seal compression, carefully and lightly wipe seal faces with a lint free cloth or remove face protective coverings.

X1.4.3 Install gland plate gasket.

X1.4.4 Bring gland plate into position and bolt it to the stuffing box face. (Warning—Excessive tightening of gland plate bolts could result in distortion and damage to the gland or the seal faces, or both.)

X1.5 **Reassemble the Pump.**

**X2. PART NUMBERING SYSTEM**

X2.1 Part numbers for mechanical seals shall include the number of this specification followed by a letter for the seal type and nine numerals to signify the grade, class, dimensions, metal component material, spring material, primary seal ring and mating ring material combinations, and elastomer component material. An example of this system is:

<table>
<thead>
<tr>
<th>Document</th>
<th>Type</th>
<th>Grade</th>
<th>Class</th>
<th>Dimens.</th>
<th>Metal</th>
<th>Spring</th>
<th>Primary</th>
<th>Elastomer</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1511</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>122</td>
<td>2</td>
<td>2</td>
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</tbody>
</table>

X2.1.1 **Type:**

X2.1.1.1 A—Inside single mounted seals (4.1.1)

X2.1.1.2 B—Outside single mounted seals (4.1.2)
C—Double seals (4.1.3)
D—Tandem seals (6.2.1)
E—Special arrangements/applications vacuum or gas seal (4.1.6)

Grade:

1—Basic end face seal (4.1.7)
2—Cartridge seal (4.1.8)
3—Split seal (4.1.9)

Class:

0—All nonsplit seals (Grades 1 and 2) (4.1.10)
1—Partial split seal assembly, solid gland (4.1.11)
2—Partial split seal assembly, split gland (4.1.12)
3—Fully split seal assembly, solid gland (4.1.13)
4—Fully split seal assembly, split gland (4.1.14)

Seal Dimensions:

001 through 030—Commercial sizes starting at 0.375 in. and increasing in 0.125–in. size intervals to 4000 in.
101 through 130—Standard long mechanical seal (Table S1)
201 through 230—Standard short mechanical seal (Table S2)
301 through 304—Special cartridge seals Grade 2 (Table S3)
401 through 405—Special seals Grade 1 (Table S4)

Metal Component Material (Table 1 and Table S5):

1—316 stainless steel
2—NiCu, NiCr, NiCrMoCb, NiMo, NiMo (Alloy B), NiMo (Alloy C), NiCrFe, or NiCrMoCo
3—Special material

Spring Material (Table 1 and Table S5):

1—316 stainless steel
2—NiCu, NiCr, NiCrMoCb, NiMo, NiMo (Alloy B), NiMo (Alloy C), NiCrFe, or NiCrMoCo
3—Special material

Primary Seal Ring Material and Mating Ring Material Combinations (Table 2 and Table S5):

1—Carbon graphite and nodular or graphitic ductile nickel cast iron
2—Carbon graphite and tungsten carbide
3—Carbon graphite and silicon carbide
4—Siliconized carbon and tungsten carbide
5—Siliconized carbon and silicon carbide
6—Silicon carbide and tungsten carbide
7—Silicon carbide and silicon carbide
8—Tungsten carbide and tungsten carbide
9—Special materials

Elastomer Component Material (Table 3 and Table S5):

1—Fluorocarbon
2—Ethylene propylene
3—Nitrile
4—PTFE
5—Corrugated graphite ribbon
6—Chloroprene
7—Special material

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Standard Specification for
Fire Hose Nozzles

This standard is issued under the fixed designation F 1546/F 1546M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, manufacture, and testing of fire hose nozzles intended for use with sea water or fresh water either in straight stream or adjustable spray patterns.

1.2 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:
   A 313/A 313M Specification for Stainless Steel Spring Wire
   A 580/A 580M Specification for Stainless Steel Wire
   A 582/A 582M Specification for Free-Machining Stainless Steel Bars
   B 117 Practice for Operating a Salt Spray (Fog) Apparatus
   D 395 Test Methods for Rubber Property—Compression Set
   D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension
   D 572 Test Method for Rubber Deterioration by Heat and Oxygen
   D 1193 Specification for Reagent Water

2.2 NFPA Standards:
   NFPA 1963 Standards for Screw Threads and Gaskets for Fire Hose Connections

3. Terminology

3.1 Definitions:

3.1.1 ball shut-off—a spray nozzle configuration that stops the flow of water through the nozzle by rotating the ball through which the water flows so that the passage no longer aligns with the nozzle flow passage.

3.1.2 break apart—a feature that allows the nozzle tip to be disconnected from the nozzle body by virtue of a coupling identical to that on the hose end of the nozzle.

3.1.3 constant flow rate spray nozzle—an adjustable pattern nozzle in which the flow is delivered at a designed nozzle pressure. At the rated pressure, the nozzle will deliver a constant flow rate from straight stream through a wide angle pattern. This is accomplished by maintaining a constant orifice size during flow pattern adjustment.

3.1.4 constant pressure (automatic) spray nozzle—an adjustable pattern nozzle in which the pressure remains constant through a range of flows rates. The constant pressure provides the velocity for an effective stream reach at various flow rates. This is accomplished by means of a pressure-activated, self-adjusting orifice baffle.

3.1.5 constant/select flow rate feature—a nozzle feature that allows on-site adjustment of the orifice to change the flow rate to a predetermined value. The flow rate remains constant throughout the range of pattern selection from straight stream to wide angle spray.

3.1.6 free swivel coupling—a coupling between the nozzle and hose or between halves of a break-apart nozzle that is capable of being turned readily by hand; that is, a spanner wrench is not required to tighten the coupling to prevent leakage.

3.1.7 flush—a feature in a nozzle that allows the orifice to be opened so that small debris that might otherwise be trapped in the nozzle, causing pattern disruptions and flow variation, can pass through. When the flush feature is engaged, the nozzle pressure will drop and the pattern will deteriorate.

3.1.8 lever-type control—a control in which the handle operates along the axis of the nozzle.

3.1.9 pistol grip—a feature usually available as an attachment that allows a nozzle to be held like a pistol.

3.1.10 rated pressure—that pressure for which the nozzle is designed to operate at a specified flow rate(s).

3.1.11 rotational-type control—a control that rotates in a plane perpendicular to the axis of the nozzle.

4. Classification

4.1 Marine fire hose nozzles may be classified into four general construction types, as follows:

4.1.1 Type I—Pistol grip, lever-type control operated.
4.1.2 Type II—Nonpistol grip, lever-type control operated.
4.1.3 Type III—Break apart, pistol grip, lever-type control operated.
4.1.4 Type IV—Break apart, nonpistol grip, lever-type control operated.
4.2 Nozzle types may be subdivided into three general classes, as follows:
4.2.1 Class I—Constant flow rate.
4.2.2 Class II—Constant/selected flow rate.
4.2.3 Class III—Constant pressure.
4.3 Classes may be subdivided into two general sizes, as follows:
4.3.1 Size 38 mm, with free swivel base.
4.3.2 Size 64 mm, with free swivel base.

5. Ordering Information
5.1 The following shall be specified when ordering:
5.1.1 Quantity,
5.1.2 Type (see 4.1),
5.1.3 Class (see 4.2),
5.1.4 Size (see 4.3),
5.1.5 Material (see 6.1.2, 9.8.1 and 12),
5.1.6 Thread type.

6. Material and Manufacture
6.1 Materials:
6.1.1 All nozzle components and parts must be durable and demonstrate satisfactory operation during all performance tests in Section 9.
6.1.2 The nozzle body and any metal used in the construction of any part of the nozzle shall be corrosion resistant. Copper alloys containing more than 15 % zinc are prohibited in all parts that are in contact with the fluid flow. No aluminum alloys may be used except for nozzles being operated exclusively with fresh water. No ferrous material may be used except for the Type 300 series stainless steel for wire and springs in accordance with Specifications A 313/A 313M or A 580/A 580M and for screws and pins in accordance with Specification A 582/A 582M.
6.1.3 All nonmetallic materials or synthetic elastomers used to form a seal or gasket shall have the following properties:
6.1.3.1 uniform dimensions,
6.1.3.2 be of such shape, size, and resiliency as to withstand ordinary usage and foreign matter carried by water, including petrochemical solvents and high alkaline solutions such as those used for cleaning nozzles (see 6.2), and
6.1.3.3 be able to withstand ozone and ultraviolet light exposure if used on the external portion of the nozzle.
6.1.4 All materials shall have tensile set of not more than 5 mm as determined in accordance with 6.2.1, and compression set not more than 15 % as determined in accordance with 6.2.2.

6.2 Specific Requirements for Rubber Sealing Materials:
6.2.1 Tensile Strength, Ultimate Elongation, and Tensile Set Tests:
6.2.1.1 Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with Test Methods D 412, Method A, except that, for tensile set determinations, the elongation shall be maintained for only 3 min, and the tensile set shall be measured 3 min after release of the specimen. The elongation of a specimen for a tensile set determination is to be such that the bench marks 25 mm apart become separated to a distance of 76 mm.
6.2.1.2 If a specimen breaks outside the bench marks, or if either the measured tensile strength or ultimate elongation of the specimen is less than the required value, an additional specimen shall be tested, and those results shall be considered final. Results of tests for specimens that break in the curved portion just outside the bench marks may be accepted if the measured strength and elongation values are within the minimum requirements.
6.2.2 Compression Set Test:
6.2.2.1 Type I specimens of the material shall be prepared and the test conducted in accordance with Test Methods D 395, Method B. The specimens shall be exposed for 22 h at 22°C.
6.2.3 Accelerated Aging Test:
6.2.3.1 Specimens shall be prepared in the same manner as for tensile strength and ultimate elongation and ultimate elongation tests, except for the bench marks 25 mm apart that shall be stamped on the specimen after the test exposure. The exposure shall be conducted in accordance with Test Method D 572.
6.2.3.2 All materials must retain not less than 70 % of the as-received tensile strength and ultimate elongation after the accelerated aging test.
6.2.4 Silicone rubber (rubber having polyorganosiloxane as its characteristic constituent) shall have a tensile strength of not less than 3.5 MPa and at least 100 % ultimate elongation as determined in accordance with 9.3.2.
6.2.5 Sealing material other than silicone rubber shall have a tensile strength of not less than 10 MPa and at least 200 % ultimate elongation as determined in accordance with 6.2.1.

7. Configuration
7.1 All nozzles shall consist of the following components and design:
7.1.1 Nozzle body,
7.1.2 Free swivel coupling,
7.1.3 Shutoffs,
7.1.4 Shutoff seats,
7.1.5 Shutoff handle,
7.1.6 Bumper guard,
7.1.7 Seals,
7.1.8 Flushing feature,
7.1.9 Piston grip (optional), and
7.1.10 Break apart feature (optional).
7.2 Nozzles shall be provided with a lever-type control shutoff handle which shall be in the closed position when the handle is closest to the discharge end of the nozzle. Lever-type control of the flow rate must also be by means of the shutoff handle.
7.2.1 The inside clearances of the shutoff handle shall be a minimum of 75 mm wide by 25 mm high.
7.2.2 The shutoff handle shall be of such a size that the operator’s hand in a fireman’s glove and closed on the handle does not interfere with the operation of the shutoff handle in any position.

7.3 Spray pattern adjustment shall be by means of rotational controls. Rotational controls shall traverse from a wide angle spray pattern to narrow angle, to straight stream in a clockwise manner when viewed from the hose coupling end of the nozzle. The wide and narrow angle spray patterns shall be enhanced with an impinging action by means of a minimum of one and a maximum of two rows of fixed or rotating teeth concentric to the discharge orifice.

7.4 Nozzles shall have a capability of clearing or flushing debris from the nozzle without shutting down the hose line. This may be accomplished either through the full open nozzle position or through a flush feature of the nozzle.

7.4.1 If used, the flush feature shall have a separate control, incorporate a detent, or shall required increased force to operate, to indicate to the firefighter when the flush feature is being engaged.

7.5 All features and controls shall be operable by one hand of the operator while the other hand is holding the nozzle.

7.6 A bumper shall be provided at the discharge end of the nozzle for protection against physical damage. The nozzle stem shall not extend past the bumper in any of the flow positions including flush.

7.7 The pistol grip, if one is provided, shall have four finger notches on the tip side and the minimum span and width shall be suitable for use with a hand wearing a typical fireman’s glove.

7.8 Couplings shall be of a free swivel type.

7.9 Each nozzle shall be provided with a resilient gasket fitted in the nozzle coupling recess. The gasket shall have dimensions in accordance with NFPA 1963. Type III and IV nozzles shall incorporate an additional gasket to accommodate the break-apart feature.

7.10 Nozzles for use with 38-mm hoses shall weigh not more than 5.9 kg. Nozzles for use with 64-mm hoses shall weigh not more than 4.53 kg.

7.11 Shutoff seats shall be self-adjusting or shall be adjustable without disassembly of the nozzle.

7.12 All features which incorporate a stop, detent, separate control, or increased force to engage shall be clearly labeled, including the open and shutoff positions, pattern selection, and flow rate selection.

8. Workmanship, Finish and Appearance

8.1 All parts and assemblies of the nozzle including castings, forgings, molded parts, stampings, bearings, machined surfaces and welded parts shall be clean and free from sand, dirt, fins, pits, spurs, scale, flux, and other foreign material. All exposed edges shall be rounded or chamfered.

9. Design Qualification Tests

9.1 Four first production run specimens shall be randomly selected and subjected to the tests described in 9.3 through 9.13 in sequential order.

9.2 The specimens shall exhibit no permanent deformation that interferes with their proper operation during any test.

9.3 Nonmetallic components shall be subjected to the following specific testing:

9.3.1 Aging Exposure:

9.3.1.1 Aging tests shall be performed before all other tests identified in this standard.

9.3.1.2 The specimens shall be subjected to air-oven aging for 180 days at 70°C and then allowed to cool at least 24 h in air at 25°C and 50 % relative humidity.

9.3.1.3 At the conclusion of the test, the specimens shall be inspected and all functions shall be operated to ensure they operate properly. Cracking, crazing, or any other condition that interferes with the proper operation of any specimen shall constitute failure of this test.

9.3.2 Ultraviolet Light-Water Exposure:

9.3.2.1 Nozzle designs with exposed nonmetallic parts shall be subjected to ultraviolet light and water for 720 h.

9.3.2.2 The ultraviolet light shall be obtained from two stationary enclosed carbon-arc lamps. The arc of each lamp is to be formed between two vertical carbon electrodes, 13 mm in diameter, located at the center of a revolvable vertical cylinder, 787 mm in diameter and 450 mm in height. Each arc is to be enclosed with a number PX Pyrex-glass globe.

9.3.2.3 The water shall conform to Type IV water in Specification D 1193.

9.3.2.4 The specimens are to be mounted vertically on the inside of the revolvable cylinder, arcing the lamps, and the cylinder continuously revolved around the stationary lamps at 1 revolution per minute. A system is to be provided so that each specimen in turn is sprayed with water as the cylinder revolves. During the operating cycle, each specimen is to be exposed to the light and water spray for 3 min and the light only for 17 min (total 20 min). The air temperature within the revolving cylinder of the apparatus during operations is to be maintained at 65°C.

9.3.2.5 At the conclusion of the test, the specimens shall be inspected and all functions shall be operated to ensure they operate properly. Cracking, crazing, or any other condition which interferes with the proper operation of any specimen shall constitute failure of this test.

9.4 Discharge Calibration Test:

9.4.1 Constant flow rate specimens shall flow the rated discharge, plus 10 %, minus 0 %, measured at rated pressure, through the entire range of pattern setting from straight stream to wide angle spray.

9.4.2 Constant/select flow rate specimens shall flow the rated discharge, plus 10 %, minus 0 %, measured at rated pressure, for each flow rate setting through the entire range of pattern setting from straight stream to wide angle spray.

9.4.3 Constant flow rate specimens and select flow rate specimens are to be installed on a piezometer fitting of the same size as the nominal inlet thread size, attached to a calibrated laboratory quality flow meter, and supplied with a source of pressurized water. The water flow rate in liters per minute is to be recorded through the full range of pattern selection.

9.4.4 Constant pressure specimens shall be tested beginning with the minimum rated flow. The pressure at this flow shall be recorded. The flow rate and nozzle pressure shall be monitored.
through the entire range of pattern selection from straight stream to wide angle spray. Any deviation over 2% in flow rate or pressure shall constitute failure of this test. The flow rate shall be slowly increased to the maximum rated flow while the pressure is monitored. At the maximum rated flow, the flow rate and pressure shall be monitored throughout the entire range of pattern selection. Any deviation over 2% in flow rate or pressure shall constitute failure of this test.

9.5 Flow Pattern Test:

9.5.1 Specimens shall develop discharge flow patterns varying from straight stream to wide angle spray while maintaining either constant flow rate or constant pressure.

9.5.2 The straight stream pattern setting shall provide a cohesive jet capable of delivering 90% of the rated flow within a circle 400 mm in diameter at a distance of 8 m from the nozzle.

9.5.3 The spray pattern settings shall provide a full and uniform spray pattern of small droplets, and the spray pattern adjustments shall provide spray pattern angles ranging from 25° for narrow angle spray through at least 120° for wide angle spray at maximum flow rate.

9.6 Flushing Test:

9.6.1 The specimens shall be held vertically, discharge end down, and the controls placed in the flush position. A 7-mm ball must pass through each specimen without changes in the flow of the stream to wide angle spray. Any deviation over 2% in flow rate and pressure shall be monitored throughout the entire range of pattern selection. Any deviation over 2% in flow rate or pressure shall constitute failure of this test.

9.7 Control Tests:

9.7.1 Lever-type controls:

9.7.1.1 Not more than 80 N nor less than 35 N shall be required to open or close the shutoff handle against a minimum of 700-kPa nozzle inlet pressure.

9.7.1.2 The specimens shall be mounted in the closed position and subjected to a static pressure of 700 kPa. A dynamometer, which records the maximum force reading, shall be attached to the shutoff handle, where the handle would normally be held during operation. The shutoff handle shall be moved from the fully closed to fully open position for the full range of pattern adjustment. The maximum force shall be recorded. Next, the specimens shall be placed in the full flowing position and the inlet pressure shall be adjusted to 700 kPa. With this new pressure adjustment, the dynamometer shall be used when moving the shutoff handle through the full range of positions and maximum force again measured and recorded. The maximum force recorded in both directions shall not be greater than permitted in 9.7.1.1.

9.7.1.3 The specimens shall be mounted without any water pressure being applied and the shutoff handle shall be placed in a closed position. The handle shall be moved from the closed position and the force required to move the handle shall be measured with the dynamometer. The force to move the handle shall not be less than permitted in 9.7.1.1.

9.7.2 Rotational-type controls:

9.7.2.1 Designs incorporating rotational controls shall have the torque required to rotate the sleeve determined while the specimen inlet pressure is 700 kPa.

9.7.2.2 A length of twine or string, not to exceed 2-mm diameter, shall be wrapped around each specimen at the point where each specimen would normally be held while rotating the sleeve. The string shall be of sufficient length to wrap around each specimen at least six turns. The first two turns will overlap the starting end of the string, and the balance of the turns will not overlap any other turn. A force gauge, which records the maximum force reading, will be attached to a loop in the free end of the string.

9.7.2.3 The sleeve shall be rotated by pulling the force gauge perpendicular to the center of the axis of each specimen. As the pattern sleeve rotates, the string will unwind, so that the force always remains tangential to the sleeve.

9.7.2.4 The sleeve shall be rotated in either direction through the entire range of rotation and the maximum torque shall be calculated. The torque shall not be more than 2 N-m nor less than 0.5 N-m.

9.7.2.5 Free swivel-type couplings shall be tested in accordance with 9.7.2.2 through 9.7.2.4. The force required to rotate each specimen once the swivel is tightened onto a coupling shall be at least 50 N not less than 5 N greater than the force required to rotate the specimen controls.

9.8 Corrosion Exposure:

9.8.1 This test is not required for aluminum nozzles because of the restriction on their use in fresh water service only.

9.8.2 The specimens shall be supported vertically and exposed to salt spray as specified by Practice B 117 for 120 h.

9.9 High Temperature Test:

9.9.1 The specimens are to be conditioned at 60°C for 24 h. Immediately after being removed from the heating chamber, the specimens shall be tested for proper function of all controls. There shall be no binding, sticking, or malfunction of any function.

9.9.2 Within 3 min of removal from the heating chamber, the specimens shall be subjected to the Rough Usage Test in 9.11.

9.10 Low Temperature Test:

9.10.1 The specimens are to be conditioned at −37°C for 24 h. Immediately after being removed from the cooling chamber, the specimens shall be tested for proper operation. There shall be no binding, sticking, or malfunction of any function.

9.10.2 Within 3 min of removal from the cooling chamber, the specimens shall be subjected to the Rough Usage Test in 9.11.

9.11 Rough Usage Test:

9.11.1 Two of the four specimens shall be connected to a dry hose and dropped twice from a height of 2 m onto a concrete surface such that the point of impact is on the lever and twice such that the point of impact is on a side 90° from the lever. The same two specimens shall then be dropped twice from a height of 600 mm such that the point of impact is squarely on the discharge end of the nozzle. The other two specimens shall be connected to a wet hose and placed in the shutoff position. The static pressure shall be increased to 700 kPa. The test from the 2-m height shall be repeated. Specimens equipped with
pistol grips shall also be dropped twice while unconnected so that the point of contact is on the grip.

9.11.2 Following the drop test, the specimens shall be examined for cracking, breaking, and deformation that interferes with their proper operation. Specimens developing cracks or broken sections or failing to operate properly are considered failed.

9.11.3 Following the drop tests, the specimens shall be subjected to the Leakage Test and Hydrostatic Pressure Test in accordance with 9.12 and 9.13, respectively.

9.12 Leakage Test:

9.12.1 The leakage test shall be conducted during the Hydrostatic Pressure Test.

9.12.2 At the point during the Hydrostatic Pressure Test in which the hydrostatic pressure is the greater of 4000 kPa or 1½ times the rated pressure, the shutoff shall be fully opened and closed. After the shutoff has been closed, the leakage shall be measured and recorded. The maximum leakage allowed through the discharge orifice is ½ mL per min. There shall be no leakage through any part of the specimens other than the discharge orifice.

9.12.3 The leakage shall be measured and recorded again when the specimens are subjected to the final hydrostatic pressure in 9.13. Increases in leakage shall not exceed 1 mL per min.

9.13 Hydrostatic Pressure Test:

9.13.1 The specimens shall be rigidly mounted in a closed position. The static pressure shall be increased to 350 kPa and held for 30 s. The static pressure shall be increased in 350-kPa increments and held for 30 s at each pressure to a maximum static pressure of 7000 kPa. The final pressure shall be held for 1 min without rupture of any specimen.

9.14 Operator Protection Test:

9.14.1 Each specimen shall be coupled to a hose and rigidly mounted at a height of 1 m to the center of the specimen body. The specimen may be slightly inclined to simulate the typical position during normal use. The pressure shall be increased to an inlet pressure of 700 kPa. The water must be clear and clean, such as that from a municipal water supply.

9.14.2 A cross or grid on which to mount radiometers shall be positioned 300 mm directly behind the specimen body. The structure shall be perpendicular to the vertical plane of the specimen.

9.14.3 Radiometers shall be mounted on the structure at a distance of 600 mm above the specimen, 300 mm to the right, 300 mm to the left, and 300 mm below the specimen.

9.14.4 A heat source, such as a grid, tree, or framework of natural gas nozzles, shall be positioned directly in front of the specimen. The heat source must be located at a horizontal distance from the specimen so that it will not be cooled when operating the specimen wide angle spray pattern.

9.14.5 The heat source shall be operated to obtain a heat flux value of at least 26 kW/m² measured by the radiometers. The specimen shall be set to the wide angle flow pattern, opened, and tested for each rated flow. The heat flux shall be recorded for each radiometer and the average calculated.

9.14.6 The average heat flux obtained during each test must be 5.7 kW/m² or lower, and no individual heat flux value may be greater than 8.0 kW/m².

9.15 Horizontal Distance:

9.15.1 The specimens shall be coupled to a hose, rigidly mounted at a height of 1 m in the open position. The flow pressure shall be set at 350 kPa.

9.15.2 The specimens shall be placed in the straight stream position. The specimens may be inclined to achieve the maximum reach. For 38-mm designs, the horizontal distance from the nozzle orifice to the center of the water pattern at its furthest point shall be at least 18 m. For 64-mm designs, this distance shall be at least 24 m.

9.15.3 The test shall be repeated with the inlet pressure increased to 700 kPa. For 38-mm designs, the horizontal distance from the nozzle orifice to the center of the water pattern at its furthest point shall be at least 27 m. For 64-mm designs, this distance shall be at least 36 m.

10. Quality Conformance Testing

10.1 Sampling for Quality Conformance Testing:

10.1.1 A quantity of completed specimens in accordance with Table 1 shall be randomly selected from each lot and subjected to the Discharge Calibration Test, Flow Pattern Test, and Leakage Test described in 9.4, 9.5 and 9.12, respectively. The Leakage Test shall be conducted using the rated pressure and the maximum leakage allowed through the discharge orifice is ¼ mL per min. If one or more defects are found in any specimen, the entire lot represented by the specimen shall be considered failed. If a lot is considered failed, the entire lot may be screened for the defective characteristic(s).

11. Certification

11.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples from each lot have been tested and inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12. Product Marking

12.1 In addition to markings required by any other section, the name of the manufacturer, the manufacturer’s model number, the size (see 4.3), the thread type, and ASTM specification designation shall be marked on each nozzle. Furthermore, all nozzles manufactured with aluminum alloys shall be marked with the phrase “F.W. Only.” All required markings, whether embossed or attached, shall be permanent and legible.

13. Keywords

13.1 fire hose; fire protection; marine; nozzle; ship; shipboard equipment

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<th>TABLE 1 Sampling for Quality Conformance Testing</th>
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<td>9–300</td>
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Standard Guide Listing
Relevant Standards and Publications for Commercial Shipbuilding

This standard is issued under the fixed designation F 1547; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This guide is a compendium of relevant publications, standards, and other information related to commercial shipbuilding.

2. Significance and Use
2.1 This guide has been developed to aid naval architects, ship designers, material and equipment suppliers, buyers, ship owners and operators, and government agencies by providing pertinent information in one document that can be used during various stages of commercial shipbuilding. These stages include design, planning, purchasing, material fabricating, assembling, testing, quality assurance, and inspection.
2.2 This guide does not specify the use of a particular standard usage nor does it detail what the standard covers.
2.3 There may be more than one standard listed for a particular product, test, or specific application. However, this guide does not compare the different standards or specify which particular standard should be used.
2.4 A partial list of sources for obtaining various standards are included below. Other sources may be located by contacting various information centers such as those at ASTM, the National Institute for Standards and Technology (Codes Standards and Information), and the American National Standards Institute. Information is also available through various sites on the Internet World Wide Web (for example, http://www.webplus.net\Unisn). When ordering, organizations should consider obtaining the latest copies of standards as complete sets or portions of sets in whatever media are appropriate (for example, hard copy, CD-ROM, or microform since purchasing, quality assurance, and engineering departments are frequently looking for information about standards called out in contract specifications, and these standards vary from one contract to another. The abbreviations used in Table 1 are defined in 2.4. Some of the sources for ordering standards are:

- ABS Americas (ABS)
  A Division of the American Bureau of Shipping
  16855 Northchase Drive
  Houston, TX 77060
  Telephone: 281–877–6000

- Air Movement and Control Association (AMCA)
  30 W. University Drive
  Arlington Heights, IL 60004
  Telephone: 708–394-0150

- American Boat and Yacht Council, Inc. (ABYC)
  3069 Solomon’s Island Road
  Edgewater, MD 21037-1416
  Telephone: 410–956-1050
  Fax: 410–956-2737

- American Gas Association (AGA)
  1515 Wilson Boulevard
  Arlington, VA 22209
  Telephone: 703–841-8400

- American National Standards Institute (ANSI)
  25 W. 43rd Street, 4th Floor
  New York, NY 10036
  Foreign/International 212–642-4995
  Domestic: 212–642-4900
  Telex: 42 42 96 ANSI UI
  Fax: 212–302-1286
  212–398-0023

- American Petroleum Institute (API)
  1220 L Street, N.W.
  Washington, DC 20005–4070
  Telephone: 202–682–8375
  Fax: 202–962–4776
  http://www.api.org

- American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE)
  Publication Sales Department
  1791 Tullie Circle, NE
  Atlanta, GA 30329

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

American Society of Mechanical Engineers (ASME)
ASME International Headquarters
Three Park Avenue
New York, NY 10016–5990

American Society of Naval Engineers (ASNE)
1452 Duke Street
Alexandria, VA 22314–3458
Telephone: 703–836–6727
Fax: 703–836–7491
e-mail: asnehz.asne@mcimail.com

American Society for Nondestructive Testing (ASNT)
Box 21142
Columbus, OH 43221

ASTM-Customer Sales and Service
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19428
Telephone: 610–832-9585
Fax: 610–832-9555
e-mail: service@local.astm.org

ASTM European Office
27-29 Knowl Piece
Wilbury Way
Hitchin, Herts SG4
OSX
England
Telephone: 0462-437933
Fax: 0462-433678

All European orders are serviced by the ASTM European Office. Customers in other countries may order from ASTM (U.S.), ASTM (Europe), or one of the following sources.

Argentina
Suministros Asociados S.A.
Belgrano 333
1642-San Isidro B.A.
Republica, Argentina
Telephone: 54–742-1466
Fax: 54–743-6461

American Books
Tucuman 994
1049 Buenos Aires
Argentina
Telephone: 54–396-3704
Fax: 54–326-3704

Australia
ACEL Information Pty. Ltd.
58 Atchison St.,
POB 471

Crows Nest NSW 2065
Australia
Telephone: 02–906-5566
Fax: 02–906-6049

Standards Association of Australia
PO Box 458
North Sydney NSW 2059
Australia
Telephone: 02–963-4111
Fax: 02–959-3896

DA Book & Journals
648 Whitehorse Road
Mitcham 3132
Victoria, Australia
Telephone: 03–873-4411
Fax: 03–873-5679

Institute of Metals and Materials Australasia Ltd.
PO Box 19
Parkville
Victoria 3052
Australia
Telephone: 03–326-7266
Fax: 03–326-7272

Brazil
SAE Brasil
Av. Paulista, 2.073
Horsa II—CJ.2.001
01311-940 Sao Paulo
Brazil
Telephone: 11–287-2627
Fax: 11–288-6599

Publicacoes Tecnias Internacionais Ltda.
R. peixoto Gomide, 209
01409 Sao Paulo-SP
Brazil
Telephone: 11–259-6644
Fax: 11–258-6990

Livrraria Independente Ltda.
Rua De Flores, 105 S/805
Parto Alegre RS
90020 Brazil
Telephone: 27-1732

China
China National Sci-Tech Information
9/F Real Estate Bldg.
Renminnan Road
Shenzhen 518001,
P.R. China
Telephone: 239290
Fax: 0755-252385

CNPIEC
No. 15 Xueyuan Lu
Beijing 10083
P.R. China
Telephone: 2010821
Fax: 2010821

Hong Kong/ Pacific Rim
Global Info Centre Hong Kong
Unit 1 11/F
Multifield Plaza
3-7A Prat Avenue
Tsim Sha Tsui
Kowloon, Hong Kong

India
Book Supply Bureau
D-44
South Extension
New Delhi-110049
India
Telephone: 11–611991
Fax: 11–692-337

Allied Publishers Private Ltd.
ASTM Dept.
751 Mount Road
Madras 600-002
India
Telephone: 44–863938, 863948, 863958
Fax: 44–470-649

Indonesia
C.V. Djakarta Raya
32, Jalan Raya
Jatinegara Timur
Jakarta Timur 13310
Indonesia
Telephone: 21–819-3487
Fax: 21–850-6529

Japan
Japanese Standards Association
1-24, Akasaka 4
Minato-Ku
Tokyo 107
Japan
Telephone: 33–583-8001
Fax: 33–586-2029

Kinokuniya Co. Ltd.
Book Division
PO Box 5050
Tokyo Intl 100-31
Japan
Telephone: 33–439-0124

Fax: 33–439-1094

Maruzen Company, Ltd.
Book Division
PO Box 5050
Tokyo 156
Japan
Telephone: 33–272-7211
Fax: 33–278-1937

Korea
Korean Standards Association
13-31 Yoido-dong
Youngdungpo-gu
Seoul, Korea 150-010
Telephone: 02–369-8114
Fax: 02–780-3340

Korea Technical Exchange Co.
Rm. 1104,
Mapo Jael Bldg.
256-13 Kongdum-dong
Mapo-ku,
Seoul 121-020
Korea
Telephone: 02–718-0391
Fax: 02–718-0569

Kumi Trading Co.
PO Box 3553
Seoul 100
Korea
Telephone: 02–588-6667
Fax: 02–588-8291

International Professional Associates
C.P.O. Box 246
Seoul 100-602
Korea
Telephone: 02–704-1733
Fax: 02–704-7585

Korea Stock Book Centre
POB 34, Yeoeido
Seoul, Korea
Telephone: 02–785-1631
Fax: 02–784-0315

Latin/South America & Mexico
Global Info Centre
3909 NE 163rd Street
Suite 110
North Miami Beach, FL 33160
Telephone: 305–944-1099
Fax: 305–944-1029

International Library Service
2722 N. 650 East
PO Box 735
Provo, UT 84601
Telephone: 801–374-6214
Fax: 801–374-0634

Mexico
IHS De Mexico
AZ. Rio Churubusco
No. 364 Col. El Carmen
Coyoacan D.F. 04100
Mexico
Telephone: 5–659-5889
Fax: 5–658-1215

New Zealand
Standards Association of New Zealand
Private Bag 2439
Wellington
New Zealand
Telephone: 04–384-2108
Fax: 04–384-3938

Pakistan
American Book & Subscription Agency
Green Hotel Bldg.
Bahadur Yar Jang Road
PO Box 3513
Karachi Pakistan
Telephone: 21–715187
Fax: 21–6312621

Singapore
Singapore Institute of Standards and Industrial Research
1 Science Park Drive
Singapore 0511
Telephone: 778-7777
Fax: 778-0086

Taiwan
Tao’s Publishers & Book Co., Ltd.
Room 502, 5th Floor
No. 121
Chung Ching S Road,
Sec. 1
Taipei Taiwan
R.O.C.
Telephone: 02–331-5773
Fax: 02–375-2555

Transmission Books & Microforms Co., Ltd.
PO Box 96-337
Taipei, Taiwan
Telephone: 02–736-7071
Fax: 02–736-3001

Bureau Veritas (BV), North America, Inc.
1850 Eller Drive
Suite 201

Everglades, FL 33316
Telephone: 954–525-4114
Fax: 954-763-9718

Canadian Standards Association
178 Rexdale Boulevard
Rexdale, ON Canada M9W 1R3
Telephone: 416–747-4058

Compressed Gas Association (CGA)
1725 Jefferson Davis Highway, Suite 1004
Arlington, VA 22202
Telephone: 703–412-0900
Fax: 703–412-0128

Customs Standards Services
802 Oakland, Suite 5
Ann Arbor, MI 48104
Telephone: 313–930-9277

Department of the Navy
(General Specifications for T Ships of the
U.S. Navy (TSGS))
Naval Sea Systems Command
Washington, DC 20362-5101

Det Norske Veritas (DNV)
North and Central America Admin.
70 Grand Avenue, Suite 201
River Edge, NJ 07661
Telephone: 201–343-0800
Fax: 201–343-4061

Document Center
Unit 9
1504 Industrial Way
Belmont, CA 94002-4044
Telephone: 415–591-7600
Fax: 415–591-7617

Document Engineering Company, Inc.
15210 Stagg Street
Van Nuys, CA 91405
Telephone: 213–873-5566

DOD Single Stock Point (DoDSSP)
Standardization Documents Order Desk
700 Robbins Avenue, Bldg. 4D
Philadelphia, PA 19111-5094
Telephone: 215–697-2179
Fax: 215–607-1462

Expansion Joint Manufacturers Association, Inc. (EJMA)
25 N. Broadway
Tarrytown, NY 10591
Telephone: 914–332-0040
Beijing 100088
Telephone: + 86 10 203 24 24
Telefax: + 86 10 203 10 10
Telegrams: 1918 beijing

Cuba (NC)
Oficina Nacional de Normalización
Calle E No. 261 entre 11 y 13
Vedado, La Habana 10400
Telephone: + 53 7 30 00 22
Telefax: + 53 7 33 80 48
Telex: 51 22 45 cencu
Telegrams: manaksanstha

Czech Republic (COSMT)
Czech Office for Standards, Metrology and Testing
Biskupsky dvur 5
113 47 Praha 1
Telephone: + 42 2 232 44 30
Telefax: + 42 2 232 43 76
Telex: 12 19 48 funmc
Telegrams: manaksanstha

Denmark (DS)
Dansk Standard
Baunegaardsvej 73
DK-2900 Hellerup
Telephone: + 45 39 77 01 01
Telefax: + 45 39 77 02 02
Telex: 11 92 03 dsstd
Telegrams: manaksanstha

France (AFNOR)
Association française de normalisation
Tour Europe
F-92049 Paris La Défense Cedex
Telephone: + 33 1 42 91 55 55
Telefax: + 33 1 42 91 56 56

Germany (DIN)
DIN Deutsches Institut für Normung
Burggrafienstrasse 6
D-10787 Berlin
Postal address:
D-10772 Berlin
Telephone: + 49 30 26 01-0
Telefax: + 49 30 26 01 12 31
Telex: 18 42 72 din
Telegrams: deutschnormen berlin
Internet: postmaster@din.de

India (BIS)
Bureau of Indian Standards
Manak Bhavan
9 Bahadur Shah Zafar Marg
New Delhi 110002
Telephone: + 91 11 323 79 91
Telefax: + 91 11 323 40 62
Telex: 316 58 70 bis in

Italy (UNI)
Enter Nazionale Italiano di Unificazione
Via Battistotti Sassi 11/b
I-20133 Milano
Telephone: + 39 2 70 02 41
Telefax: + 39 2 70 10 61 06
Telegrams: unificazione

Japan (JISC)
Japanese Industrial Standards Committee
C/o Standards Department
Ministry of International Trade and Industry
1-3-1, Kasumigaseki, Chiyoda-ku
Tokyo 100
Telephone: + 81 3 35 01 92 95
Telefax: + 81 3 35 80 14 18
Telex: 02 42 42 45 jsatyo j
Telegrams: mitijisc tokyo

Korea, Dem. P. Rep. of (CSK)
Committee for Standardization of the Democratic People’s Republic of Korea
Zung Gu Yok Seungli-Street
Pyongyang
Telephone: + 85 02 57 15 76
Telex: 59 72 tech kp
Telegrams: standard

Korea, Republic of (KIAA)
Industrial Advancement Administration (KIAA)
2, Chungang-dong, Kwachon-city
Kyonggi-do 427-010
Telephone: + 82 2 503 79 38
Telefax: + 82 2 503 79 41
Telex: 2 84 56 fincen k
Telegrams: koreaiaa

Netherlands (NNI)
Nederlands Normalisatie-instituut
Kalfjeslaan 2
PO Box 5059
NL-2600 GB Delft
Telephone: + 31 15 2 69 03 90
Telefax: + 31 15 2 69 01 90
Telex: 3 81 44 nni nl
Telegrams: normalisatie delft

Norway (NSF)
Norges Standardiseringsforbund
Hegdehaugsveien 31
Postboks 7020 Homansbyen
N-0306 Oslo 3
Telephone: + 47 22 46 60 94
Telefax: + 47 22 46 44 57
Poland (PKN)
Polish Committee for Standardization
ul.Elektoronalna 2
PO Box 411
00-950 Warszawa
Telephone: + 48 22 620 54 34
Telefax: + 48 22 620 07 41

Romania (IRS)
Institutul Român de Standardizare
Str. Jean-Louis Calderon Nr. 13
Cod 70201
Bucuresti 2
Telephone: + 40 1 211 32 96
Telefax: + 40 1 210 08 33

Russian Federation (GOST R)
Committee of the Russian Federation for Standardization,
Metrology and Certification
Leninsky Prospekt 9
Moskva 117049
Telephone: + 7 095 236 40 44
Telefax: + 7 095 237 60 32
Telex: 41 13 78 gost su
Telegrams: moskva standart

USA (ANSI)
American National Standards Institute
11 W. 42nd Street
13th Floor
New York, NY 10036
Telephone: + 1 212 642 49 00
Telefax: + 1 212 398 00 23
e-mail: smazza@ansi.org

United Kingdom (BSI)
British Standards Institution
389 Chiswick High Road
GB-London W4 4AL
Telephone: + 44 181 996 90 00
Telefax: + 44 181 996 74 00

Lloyd’s Register of Shipping (LR)
17 Battery Place
New York, NY 10004-1195
Telephone: 212–425-8050
Fax: 212–363-9610

Manufacturers Standardization Society (MSS)
127 Park Street, NE
Vienna, VA 22180
Telephone: 703–281-6613
Fax: 703–281-6671

Maritime Administration
National Maritime Resource and Education Center—
Marine Standards Library
400 Seventh Street, SW

Washington, DC 20590
Telephone: 202–366-1864
Fax: 202–366-7197

Morgan Technical Library
National Fire Protection Association
Batterymarch Park, Room 251
Quincy, MA 02269
Telephone: 617–770-3000, ext. 445

National Electrical Manufacturers Association (NEMA)
2101 L. Street, NW
Washington, DC 20036

National Fire Protection Association (NFPA)
PO Box 9146
Quincy, MA 02169
Telephone: 800–344-3550
Fax: 617–984-7057

National Institute of Standards and Technology (NIST)
Room A629, Administration Building
Standards Information Center
Gaithersburg, MD 20899
Telephone: 301–975-4040

Naval Sea Systems Command (NAVSEA)
Department of the Navy
CODE 03R4
National Center Building 3
2531 Jefferson Davis Highway
Arlington, VA 22202
Telephone: 703–602-1135
Fax: 703–602-6363

Nippon Kaiji Kyokai
One Parker Plaza, 11th Floor
400 Kelby Street
Fort Lee, NJ 07024
Telephone: 201–944-8021
Fax: 201–944-8183

Oil Companies International Marine Forum (OCIMF)
6th Floor, Portland House, Stag Place
London, SWIE 5BH, England

Radio Technical Commission for Marine Services
(RTCMS)
Box 19087
Washington, DC 20036
Telephone: 202–639-4006

Society of Automotive Engineers, Inc. (SAE)
400 Commonwealth Drive
Warrendale, PA 15096

Society of Allied Weight Engineers, (SAWE), Inc.
5530 Aztec Drive
La Mesa, CA 91942–2110
Telephone: 619–465–1367
Fax: 619–465–2561
E-mail: saweedge@king.cts.com

Society of Naval and Marine Engineers (SNAME)
601 Pavonia Avenue
Jersey City, NJ 07306
Telephone: 800–798–2188 or 219–798–4800
Fax: 219–798–4975
E-mail: sname@sname.org

Standards Engineering Society
1706 Darst Avenue
Dayton, OH 45403
Telephone: 513–258-1955
Fax: 513–258–0018

Superintendent of Documents
Government Printing Office
Washington, DC 20402
Telephone: 202–512-1800
Fax: 202–512-2250
U.S. Fax Watch: 202–512-1716

This ordering address applies to the following:
Code of Federal Regulations (CFR)
Department of Health and Human Services (DHHS)

Technical Standards Service
4024 Mt. Royal Boulevard
Allison Park, PA 15101
Telephone: 412–487-7007

Underwriters Laboratories (UL)
33 Pfingsten Road
Northbrook, IL 60062
Telephone: 312–272-8800

U.S. Coast Guard (USCG)
Department of Transportation
2100 Second Street, SW
Washington, DC 20593
Telephone: 202–366-6483
Fax: 202–366-3877

3. Standards and Publications

3.1 Table 1 lists standards and publications, subdivided into nine groups. If you do not find a standard in one group, check to see if it is in a related group.

4. IACS Member Societies

4.1 The International Association of Classification Societies (IACS) Member Societies are listed below. These Classification Societies have established IACS to promote the highest standards in ship safety and the prevention of marine pollution. IACS provides consultation and cooperation with IMO. The Member Societies are strictly bound by ISO based Quality Assurance Standards for Ship Classification and delegated statutory work.

Societies

American Bureau of Shipping (ABS)
ABS Plaza
16855 Northchase Drive
Houston, TX 77060
Tel: 281–877–6000

Bureau Verities (BV)
17 bis, Place des Reflets
La Defense 2
92040 Courbevoie, France
(Postal address: Cedex 44-92077 Paris-La-Defense, France)
Tel: (33-1) 42 91 52 91
Tlx: (842) 61538F BVSMG
Fax: (33-1) 42 91 52 93

China Classification Society (CCS)
40, Dong Huang Cheng Gen Nan Jie
Beijin 10006
China
Tel: (86-1) 513-6633
Tlx: (718) 210407 ZCBJ CN
Fax: (86-1) 513 0188

Det Norske Veritas (DNV)
Veritasveien 1
PO Box 300
N-1322 Hovik
Norway
Tel: (47-67) 57 99 00
Tlx: (856) 76 192 VERIT N
Fax: (47-67) 57 99 11

Germanischer Lloyd (GL)
Vorszetzen 32
PO Box 11 16 06
D-2000 Hamburg 11
Germany
Tel: (49-40) 361490
Tlx: (841) 212628 GLHH D
Fax: (49-40) 36149200

Korean Register of Shipping (KR)
1485-10 Seocho-Dong
Seocho-Ku, Seoul, Korea
PO Box 3229
Tel: (82-2) 5826001
Tlx: (787) 27358 K
Fax: (82-2) 5848813


Associates

Hravatski Registar Brodova (CRS)
Croatian Register of Shipping
Split 58000
Croatia
Tel: (385) 48-955
Tlx: (862) 26129 HR CROREG
Fax: 585-746

Indian Register of Shipping
72 Maker Towers F, 7th Floor
Cuffe Parade
Bombay 400-005
Tel: (953) 83364 IRISIN
Fax: (91-22) 2181241

This ordering address applies to the following:
Code of Federal Regulations (CFR)
Department of Health and Human Services (DHHS)
4.2 Delegating Countries—The countries delegating statutory responsibilities to Classification Societies are listed in Table 2. We have received this information from only five of the IACS Member Societies. The abbreviations used are discussed at the end of Table 2.

5. IACS Member Societies with Offices in the United States—Publication Lists

5.1 ABS—American Bureau of Shipping & Affiliated Companies—Publications

5.1.1 For current prices and information concerning publications:

**ABS Americas:**

ABS Plaza
16855 Northchase Drive
Houston, TX 77060
Tel: 281–673-0700
Fax: 281–874-9551

**ABS Europe:**

ABS House, 1 Frying Pan Alley
London, E1 7HR England
Tel: (44-171) 247-3255
Telex: 865621
Fax: (44-171) 377-2453

**ABS Pacific:**

510 Thomson Road
No. 06-00, SFL Bldg.
Singapore 1129
Republic of Singapore
Tel: 65–353-5713
Telex: RS 34264
Fax: 65–353-3454

5.1.2 ABS Publication List:

5.1.2.1 Classification Register:

<table>
<thead>
<tr>
<th>Title</th>
<th>Ref. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record of ABS (Annual) 1998 edition</td>
<td>00</td>
</tr>
</tbody>
</table>

5.1.2.2 Rules for Building and Classing:

<table>
<thead>
<tr>
<th>Title</th>
<th>Ref. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Vessels 1998—Complete set of rules including all notices and updates</td>
<td>2</td>
</tr>
<tr>
<td>Aluminum Vessels (1975), RCN-3-5, 1-A</td>
<td>3</td>
</tr>
<tr>
<td>Steel Vessels for Service on Rivers and Intracoastal Waterways (1997), RCN5</td>
<td>4</td>
</tr>
<tr>
<td>Steel Vessels Under 90 Meters (295 Feet) in Length (1997)</td>
<td>5</td>
</tr>
<tr>
<td>Mobile Offshore Drilling Units (1997)</td>
<td>6</td>
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</tbody>
</table>

5.1.2.3 Rules For:

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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Underwater Vehicles, Systems, and Hyperbaric Facilities (1990), RCN-1</td>
<td>7</td>
</tr>
<tr>
<td>Single Point Mooring (1996)</td>
<td>8</td>
</tr>
<tr>
<td>Bulk Carriers for Service on the Great Lakes (1978), RCN-1 and 2</td>
<td>9</td>
</tr>
<tr>
<td>Steel Barges (1991), RCN 1–4 and corr. #1, also available on CD-ROM</td>
<td>10</td>
</tr>
<tr>
<td>Steel Floating Drydocks (1977)</td>
<td>11</td>
</tr>
<tr>
<td>Reinforced Plastic Vessels (1978), RCN 1-2</td>
<td>12</td>
</tr>
<tr>
<td>Offshore Installations (1997)</td>
<td>29</td>
</tr>
</tbody>
</table>

5.1.2.4 Preliminary Rules For:

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</tr>
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<tr>
<td>Certification of Cargo Containers (1987)</td>
<td>13</td>
</tr>
<tr>
<td>Nondestructive Inspection of Hull Welds (1986)</td>
<td>14</td>
</tr>
</tbody>
</table>

5.1.2.5 Guide For:

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<thead>
<tr>
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<th>Ref. No.</th>
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</thead>
<tbody>
<tr>
<td>Building and Classing Accommodation Barges and Hotel Barges (1989), RCN 1</td>
<td>48</td>
</tr>
</tbody>
</table>

Underwater Vehicles, Systems, and Hyperbaric Facilities (1990), RCN-1
Single Point Mooring (1996)
Bulk Carriers for Service on the Great Lakes (1978), RCN-1 and 2
Steel Barges (1991), RCN 1–4 and corr. #1, also available
on CD-ROM
Steel Floating Drydocks (1977)
Reinforced Plastic Vessels (1978), RCN 1-2
Offshore Installations (1997)

5.1.2.3 Rules For:

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<td>48</td>
</tr>
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<table>
<thead>
<tr>
<th>Title</th>
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<td>Building and Classing High Speed Craft, 1997</td>
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<td>Building and Classing Motor Pleasure Yachts, (1990), Corr-1, RCN 1</td>
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<td>Building and Classing Facilities on Offshore Installations (1991)</td>
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<td>Building and Classing Undersea Pipeline Systems and Risers (1991)</td>
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<td>Building and Classing Oil Recovery Vessels (1997), Corr-1–2</td>
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<tr>
<td>Assessing Hull-Girder Residual Strength for Tankers (1995)</td>
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<td>Improvement for Structural Connections and Sample Structural Details-Service Experience and Modifications for Tankers (1995)</td>
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<tr>
<td>Dynamic Based Design and Evaluation of Double Hull Tanker Structures Between 150 and 190 Meters in Length (1995), Corr 1–2</td>
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5.1.2.6 Guidance Manual For:

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5.1.2.7 Requirements For:

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<tr>
<td>Certification of Self-Unloading Cargo Gear on Great Lakes Vessels (1991)</td>
<td>25</td>
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<td>Certification of the Construction and Survey of Cargo Gear on Merchant Vessels (1975)</td>
<td>26</td>
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<td>Approved Welding Combinations (1998)</td>
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<tr>
<td>Notes on Heavy Fuel Oil (1984)</td>
<td>31</td>
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<tr>
<td>List of Type Approved Equipment (1998)</td>
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<tr>
<td>International Workshop on Underwater Welding of Marine Structures</td>
<td>46</td>
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5.2 Bureau Veritas (Marine Division)—Technical Publications

5.2.1 For information, current prices, and orders concerning publications:

Bureau Veritas
Direction Division Marine—D.S.M./PUB
17 bis, place des Reflets—92400 La Defense 2
Post Adres.: 92077 Paris-La Defense Cedex
Tel: 33 (0) 1 42 91 52 91
Fax: 33 (0) 1 42 91 52 98

5.2.2 Marine Technical Publications List:

5.2.2.1 Rules:

<table>
<thead>
<tr>
<th>Title</th>
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<td>Chapter 4: Subdivision and Intact Stability (3/1996)</td>
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<tr>
<td>Chapter 5: Hull Structure Design—Steel Ships of More than 65 m in Length (9/1997)</td>
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<tr>
<td>Chapter 6: Hull Structure Design—Steel Ships of Less than 65 m in Length (9/1997)</td>
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<td>Chapter 8: Provisions Applicable to Some Service Notations (9/1997)</td>
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<td>Chapter 9: Hopper Dredgers and Split Hopper Dredgers (3/1996)</td>
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<tr>
<td>Chapter 14: Hull Outfittings (3/1996)</td>
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<tr>
<td>Part III “Machinery Systems” (9/1997)</td>
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<td>Chapter 15: Piping Systems—Miscellaneous Installations (9/1993)</td>
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<td>Chapter 16: Boilers and Pressure Vessels (3/1996)</td>
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<td>Chapter 17: Propelling and Auxiliary Machinery (3/1996)</td>
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<td>Chapter 18: Electrical Installations (9/1997)</td>
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<tr>
<td>Chapter 21: Refrigerating Plants (3/1996)</td>
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<tr>
<td>Chapter 22: Ships for the Carriage of Liquefied Gases (3/1996)</td>
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<td>Chapter 23: Ships Carrying Liquid Cargoes in Bulk (3/1996)</td>
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<tr>
<td>Chapter 24: Harbor and Offshore Working Ships or Units—Fishing Vessels—Livestock Carriers (3/1996)</td>
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<tr>
<td>Chapter 25: Propelled Ships of Less than 24 m in Length (9/1997)</td>
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<tr>
<td>Rules for the Classification-Certification of Yachts (1993)</td>
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<td>Rules and Regulations for the Classification of Submersibles (1989)</td>
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<tr>
<td>Rules and Regulations for the Classification of Mobile Offshore Drilling Units (1987)</td>
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<tr>
<td>Amendments No. 1 (including Leaflet 3/85 and 1/95)</td>
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<tr>
<td>Chapters 1 and 2: Classification Surveys (9/1997)</td>
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5.2.2.2 Notes:

5.2.2.2.1 Rule Notes:
5.2.2.2 Guidance Notes:

Title Ref. No.
Study on sloshing and partial filling (1984) NI 171 DNC R00 E
Noise on board ships (1981) NI 174 DNC R00 E
Underwater welding. General information and recommendations (1985) NI 198 DNC R00 E
Cyclic fatigue of nodes and welded joints of offshore units (1987) NI 199 DNC R00 E
Bollard pull measurement and certification (1985) NI 202 DNC R00 E
Guidelines on documents to be submitted for stability study (1988) NI 299 DNC R00 E
Non-bonded flexible steel pipes used as flow-lines (1990) NI 364 DTO R00 E
Practical guide for the certification of composite yacht hulls under the BV Mode I survey scheme (1993) NI 385 DNP R00 E/F
Thickness measurements—Requirements—Interpretations—Acceptance criteria (1997) NI 389 DNS R01 E
Fatigue strength of welded ship structures (1995) NI 393 DSM R00 E
Programme for condition assessment survey (PCAS) (1995) NI 395 DNS R00 E
Recommendations to avoid overloading of bulk carrier structures (1995) NI 402 DNC R00 E
Guidelines for corrosion protection of seawater ballasts tanks and hold spaces (1995) NI 409 DNC R00 E
Recommendations on the quality of software on board (1996) NI 425 DNC R00 E/F
Guidelines for the preparation of cargo securing manual (1997) NI 429 DNC R00 E
Guidance note for the certification of lifesaving appliances and arrangements (1997) NI 430 DNC R00 E
Certification of synthetic fiber ropes for mooring systems (1997) NI 432 DTO R00 E
Type approval of non-destructive testing equipment dedicated to underwater inspection of offshore structures (1998) NI 422 DTO R00 E

5.2.2.3 General Notes:

Title Ref. No.
List of approved steels. (1994) NG 259 DSC R01 E/F
Type approved materials and equipment. Electrical control and monitoring equipment. (1996) NG 260 DSC R04 E
Type approved materials and equipment. Statutory materials and equipment. (1996) NG 263 DSC R06 E
Approved filler products for electric arc welding. (1998) NG 313 DSC R09 E/F
Type approved processes materials and equipment. Hull and Machinery. (1996) NG 363 DSC R05 E

5.3 Det Norske Veritas—Publications:

List of approved steels. (1994) NG 259 DSC R01 E/F
Type approved materials and equipment. Electrical control and monitoring equipment. (1996) NG 260 DSC R04 E
Type approved materials and equipment. Statutory materials and equipment. (1996) NG 263 DSC R06 E
Approved filler products for electric arc welding. (1998) NG 313 DSC R09 E/F
Type approved processes materials and equipment. Hull and Machinery. (1996) NG 363 DSC R05 E

Det Norske Veritas Classification
80 Grand Avenue Suite 201
River Edge, NJ 07661
5.3.2 Det Norske Veritas—Publication List:

5.3.2.1 Rules for Classification of Ships:

Complete Volume (includes binder and introduction booklet)
Annual Subscription Fee (includes all new and revised chapters issued)
CD-ROM version for IBM compatible PC, single user
Initial price
Twice yearly updates—annual subscription free
CD-ROM, network licenses
Reprints of the Rules for Ships (separate booklets)

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| Chapter 4: Electrical Installations                                     |
| Chapter 5: Instrumentation and Automation                               |
| Chapter 6: Fire Protection, Detection and Extinction                    |
| Part 5: Special Service and Type—Additional Class                      |
| Chapter 1: Units for Transit and/or Location in Ice                     |
| Chapter 2: Accommodation Vessels and other Offshore Support Vessels     |
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| Chapter 4: Oil Production and Storage Units                             |
| Chapter 5: Offshore Loading Buoys                                       |
| Part 6: Special Equipment and Systems—Additional Class                  |
| Chapter 1: Miscellaneous Notations                                     |
| Chapter 2: Position Mooring (POSMOOR)                                    |
| Chapter 3: Periodically Unattended Machinery Space (EO)                  |
| Chapter 4: Additional Fire Protection (F-AM)                            |
| Chapter 5: Drilling Plant (DRILL)                                        |
| Chapter 6: Oil Production Plant (PROD)                                   |
| Chapter 7: Dynamic Positioning Systems                                  |

5.3.2.2 Rules for Classification of Mobile Offshore Units:

Complete Volume (includes binder and introduction booklet)
Annual Subscription Fee (includes all new and revised chapters issued)
Reprints of the Rules for Mobile Offshore Units (separate booklets):

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5.3.2.3 Rules for Classification of Fixed Offshore Installations:

Complete Volume (includes binder and introduction booklet)
Annual Subscription Fee (includes all new and revised chapters issued)
Reprints of the Rules for Fixed Offshore Installations (separate booklets):

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<td>Chapter 4: Mechanical Equipment</td>
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<td>Chapter 7: Precommissioning</td>
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<td>Chapter 8: Systems Related to Special Designs</td>
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<td>Part 5: Special Function</td>
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5.3.2.4 Tentative Rules for Classification of High Speed and Light Craft:

Complete Volume (includes binder and introduction booklet)
Annual Subscription Fee (includes all new and revised chapters issued)
Reprints (separate booklets):

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Chapter 1 Steel and Iron
Chapter 2 Aluminium, Copper, and Non-Ferrous Alloys
Chapter 3 Welding
Chapter 4 Fibre Composite and Sandwich Materials
Part 3 Structures, Equipment
Chapter 1 Design Principles, Design Loads
Chapter 2 Hull Structural Design, Steel
Chapter 3 Hull Structural Design, Aluminium Alloy
Chapter 4 Hull Structural Design, Fibre Composite and Sandwich Constructions
Chapter 5 Equipment, Steering and Appendages
Part 4 Machinery and Systems—Equipment and Operation
Chapter 1 Machinery and Hull Piping Systems
Chapter 2 Propulsion, Auxiliary Machinery and Pressure Vessels
Chapter 3 Electrical Installations
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Chapter 5 Fire Safety
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Chapter 1 Passenger Craft
Chapter 2 Car Ferry
Chapter 3 Cargo
Part 6 Special Equipment and Systems—Additional Class
Chapter 1 Periodically Unattended Machinery Space (EO)
Chapter 2 Nautical Safety

5.3.2.5 Certification Notes:
Quality Assurance Systems:
1.1 Conformity Certification Services—General Description, November 1988
1.2 Conformity Description, November 1988—Type Approval, January 1990
1.3 Conformity Certification Services—Quality System Certification, May 1990
1.5 Conformity Certification Services—Approval of Manufacturers, Metallic Materials, September 1990

Approval Schemes:
2.1 Approval and Survey Programs for Materials, October 1988
MAT 100—Approval of Manufacturers, Ferrous and Non-Ferrous Materials and Material Products
MAT 200—Manufacturing Survey, Ferrous and Non-Ferrous Materials and Material Products
MAT 300—Approval of Manufacturer and Manufacturing Survey, Mooring Equipment
MAT 400—Approval of Welding Consumables
MAT 500—Type Approval of Non-Metallic Materials and Material Products
MAT 600—Approval of Corrosion Protection Systems
2.4 Type Approval of Instrumentation and Automation Equipment, March 1988
2.5 Type Approval of Loading Instruments for Ships, June 1985
2.6 Certification of Offshore Mooring Chain, July 1985
2.7-1 Offshore Freight Containers, May 1989
2.8 On Board Stability Computers, February 1990
2.9 101 Type Approval, Valves, November 1991
102 Type Approval, Pipe Couplings, November 1991
103 Type Approval, Flexible Hoses of Non-Metallic Materials, November 1991
201 Approval Program, Approval of Hydraulic Cylinders
2.10 Diesel Engine Driven Power Plants—Certification, Testing, and Inspection, July 1991

Marine Operations:
3.3 Declarations on Lay-up of Ships, August 1983
3.4 Declarations on Preservation of Lay-up Ships, August 1976

5.3.2.6 Register Book
Det Norske Veritas’ Register Book (including 4 supplements)
5.3.2.7 Guidelines and Classification Notes:
Complete Volume (purchase basis)
Annual Subscription Fee (includes all new and revised notes issued)
Design and Classification of Roll-On/Roll-Off Ships, May 1980
Prevention of Harmful Vibration in Ships, July 1983
Internal Control, Mobile Offshore Units (Owners’ Control System) September 1983
Stability Documentation for Mobile Offshore Units Class and Statutory Services, November 1986
Documentation Required for SC Class, June 1988
Condition Assessment Program, September 1991
Safety and Quality Management, May 1992
Guidelines for Corrosion Protection of Ships, July 1992
4.1 Guidance Manual for Inspection and Repair of Bronze Propellers, October 1992
4.2 Guidance Manual for Inspection and Repair of Steel Propellers, October 1992
6.1 Fire Test Methods for Plastic Pipes, Joints, and Fittings, January 1987
7. Ultrasonic Inspection of Weld Connections, May 1980 (Reprint of November 1978)
10.1 Ships and Mobile Offshore Units, Alternative Survey Arrangements for Machinery and Automation Systems, August 1992
20.1 Stability Documentation—Ships (Newbuildings), February 1990
20.2 Lightweight Determination—Ships, February 1990
30.1 Buckling Strength Analysis, May 1992
30.2 Fatigue Strength Analysis for Mobile Offshore Units, August 1984
30.3 Spherical Shells Subjected to Compressive Stresses, October 1987
30.4 Foundations, February 1992
30.5 Environmental Conditions and Environmental Loads, March 1991
30.6 Structural Reliability Analysis of Marine Structures, July 1992
31.1 Strength Analysis of Hull Structures in Bulk Carriers and Container Ships, May 1980
31.2 Strength Analysis of Hull Structures in Roll-On/Roll-Off Ships, May 1980
31.3 Strength Analysis of Hull Structures in Tankers, October 1988
31.4 Strength Analysis of Main Structures of Column Stabilized Units (Semi-submersible Platforms), September 1987
31.5 Strength Analysis of Main Structures of Self-Elevating Units, February 1992
32.1 Strength Analysis of Rudder Arrangements, January 1984
32.2 Strength Analysis of Container Securing Arrangements, July 1983
41.2 Calculation of Gear Rating for Marine Transmission, August 1990
41.3 Calculation of Crankshafts for Diesel Engine, July 1988
42.1 Dual Fuel Arrangement for Diesel Engines with High Pressure Gas Injection, February 1989
5.3.2.8 Lists of Type Approved Manufacturers and Type Approved Products:
Approved Manufacturers:
100. Companies with Veritas Certified Quality Systems
101. Metallic Materials
Type Approved Products:
1. Nonmetallic Materials
2. Welding Consumables
3. Structural Equipment, Containers, Cargo Handling, and Securing Equipment
4. Machinery Components
5. Mechanical Equipment and Piping
6. Electrical Equipment and Systems
7. Instrumentation and Automation
8. Fire-Restricting Materials and Fire Technical Equipment
9. Drilling and Well Control Equipment
5.3.2.9 Rules for Other Objects:
Translation of Tentative Rules for the Construction and Classification of Vessels of Glass Reinforced Plastics (1972) Norwegian and English Editions
Tentative Rules for the Construction and Classification of Dynamic Positioning Systems for Ships and Mobile Offshore Units, 1977
Rules for the Construction and Classification of Floating Docks, 1977
Rules for Certification of Lifting Appliances, 1989
Rules for Certification of Freight Containers, 1981
Rules for Certification of Dividing Systems, 1988
Rules for Certification of Lifts, 1987
Rules for Certification/Classification of Submersibles, 1988
Rules for Lifeboats Based on SOLAS 1974 Amendment 83 Rev. Ch. 3, 1986
5.4 Germanischer Lloyd—English Publications
5.4.1 For current prices and information concerning publications:
Germanischer Lloyd
PO Box 11 16 06, D-20416 Hamburg
Vorsetzen 32, D-20459 Hamburg
Tel: (040) 36 14 90
Telex: 2 12 828 glhh d
Fax: (040) 36 14 92 00

5.4.2 Germanischer Lloyd—Publication List:

Note: 1—This list includes all English titles, in which the publication is available.

5.4.2.1 Ship Technology:

<table>
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5.4.2.2 Materials and Welding:

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<td>Regulations for Lifesaving—Launching Appliances (1986)</td>
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<td>Regulations for the Construction and Survey of Lifting Appliances (1992)</td>
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<td>Regulations for Testing of Steam Boiler Plants in Accordance with the Dampkessel-verordnung (German Boiler Regulations) for Seagoing Ships Under the Federal German Flag (1991)</td>
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<td>Structural Fire Protection for Ships and Offshore Structures—List of Approvals (1992)</td>
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#### 5.5 Lloyds Register (LR)—Publications

For current prices and information concerning publications:

- **International Headquarters of the LR Group**
  - Lloyd’s Register
  - 100 Leadenhall Street
  - London EC3A 3BP, United Kingdom
  - Tel: +44 171 709 9166
  - Tlx: 888379 LR LONG
  - Fax: +44 171 488 4796

- **North America Regional Office**
  - Lloyd’s Register of Shipping
  - 17 Battery Place
  - New York, NY 10004
  - Tel: (212) 425–8050
  - Fax: (212) 363–9610

**5.5.2 Lloyds Register (LR)—Publication List:**

- **5.5.2.1 Rules and Regulations (Marine):**
  - Rules and Regulations for the Classification of Ships 1993—Based on combination of long practical experience and advanced theory, the rules are constantly revised to take account of new developments in merchant shipbuilding. They are
intended primarily for use by naval architects, shipbuilders, and marine engineers. A complete set consists of seven separate parts contained in a Substantial binder.

The complete set, together with four-ring binder and LR's List of Approved Manufacturers of Materials, Recognized Proving Establishments, Class 1 Welding Firms and Firms Approved for Product Certification by Surveillance of Quality Systems.

All Parts from the Rules are available individually:


Part 3—Ship Structures—The basic structural philosophy of hull construction, longitudinal strength, aft end structures, superstructures, and so forth.

Part 4—Ship Structures—Hull construction requirements for specific ship-types—for example, tugs, ferries, bulk carriers, oil tankers, and containerships.

Part 5—Main and Auxiliary Machinery—Main and auxiliary machinery including shaft vibration and alignment, piping systems for oil and chemical tankers, and steering gear.

Part 6—Control, Electrical, Refrigeration, and Fire—Automation and control systems, electrical systems, refrigeration systems and fire prevention systems.

Part 7—Special Types—Highly specialized ships to which the format of the rest of the Rules cannot easily be applied—that is, nuclear ships; ships with installed process plant; fire fighting ships; dynamic positioning installed in ships; oil recovery ships; ship to shore ramps and linkspans; burning of coal in ships’ boilers; positional mooring systems and thruster assisted positional mooring systems.

Four-Ring Binder—With 55-mm capacity and blocked “Rules and Regulations.”

LR PASS (Plan Appraisal Systems for Ships)

Current Facilities

Rules programs for IBM/PC and compatible computers

Direct calculations programs for IBM/PC and compatible computers

Feedback and Improvement Procedure

Rules for Inland Waterway Ships—A complete set consists of the five parts contained in a substantial binder.

All parts are available individually:

Part 1—Regulations

Part 2—Materials for Ship and Machinery

Part 3—Ship Structure

Part 4—Ship Structure

Part 5—Main and auxiliary Machinery

Part 6—Control, Electrical and Fire

Binder—(With 55-mm capacity and blocked “Rules and Regulations.”)

Rules for Floating Docks 1987

Code for Lifting Appliances in a Marine Environment 1987—Requirements for ship derricks and deck cranes, offshore and floating cranes, lifts and ramps, launch and recovery systems for diving operations and mechanical lift docks.


5.5.2.2 Rules and Regulations (Offshore):

Rules and Regulations for the Classification of Mobile Offshore Units 1989—The Rules now appear in six Parts contained in a substantial binder (included in the price) and with Materials from the Rules and Regulations for the Classification of Ships.

Various Parts from the Rules are available:

Part 1—Regulations—Classification and periodical surveys.

Part 2—Materials—Conditions for manufacture, survey and certification, and requirements for high holding power anchors and special quality chain cable.

Part 3—Structure—Unit structural requirements, unit types, strength, mooring equipment, and steering arrangements.

Part 4—Stability, Watertight/Weather tight Integrity and Corrosion Control—Requirements for stability, load lines, watertight and weathertight integrity, guard rails, bulwarks and corrosion control.

Part 5—Main and Auxiliary Machinery—Main and auxiliary machinery including shaft vibration and alignment, piping systems, pressure vessels and steering gear.

Part 6—Control, Electrical, Hazardous Areas and Fires—Control systems, electrical systems, hazardous areas, fire fighting units and dynamic positioning systems.

Four-Ring Binder—With 40-mm capacity and blocked “Rules and Regulations.”

Rules and Regulations for the Construction and Classification of Submersibles and Underwater Systems 1989

Rules and Regulations for the Classification of Fixed Offshore Installations 1989—The rules are based on LR’s experience from the certification of over 600 platforms worldwide. Like all other LR rules, they are based on a mixture of experience and theoretical innovation. They are primarily intended for operators and designers in areas where national authorities have no requirements of their own. A complete set consists of eight parts contained in a binder.

All parts are available individually:


Part 2—Materials and Manufacturing Procedures—Material selection for both the jacket structure and machinery components. This part is accompanied by Materials of the Rules and Regulations for the Classification of Ships and includes a chapter covering Quality Assurance Scheme for the Construction of Fixed Offshore Installations.

Part 3—Environmental and Design Considerations—Approval of each installation is site specific including complete assessment of all environmental factors and ocean bed conditions. The jacket and module structures are examined for a variety of external loads imposed by the elements and the
distribution of weight on the platform. Also includes gravity
foundaiton design.

Part 4—Steel Structures—The structural arrangements of
each installation are independently examined and advice given
on acceptable analysis techniques, factors of safety and fatigue
design.

Part 5—Concrete Structures—All aspects of concrete struc-
tures including materials, fabrication, and assessment are
covered.

Part 6—Corrosion Protection—Active and passive cathodic
protection systems, coating and painting systems.

Part 7—Machinery and Process Systems—Regulations for
drilling and process equipment on platform and subsea, includ-
ing pressure vessels and pressure systems, heating, ventilation,
and air conditioning. Mechanical, electrical, control engineer-
ing, and hazardous areas are included.

Part 8—Fire and Safety Equipment—Passive and active fire
safety measures, both fixed and portable. Safety equipment
including lifesaving appliances and radio communications.

Four-Ring Binder—With 40-mm capacity and blocked
“Rules and Regulations.”

Container Certification Scheme 1988—Rules for the design,
construction, and inspection of general cargo containers, ther-
cmal containers (both insulated and refrigerated), tank contain-
ers and other portable tanks; container trailer/vehicle chassis;
in-service inspection of containers, tanks, and carrying tanks of
road containers; basic quality system requirements for manu-
facturer; ISO test procedures.

5.5.2.3 Approved Products:
LR-Type Approval System 1990—Advice to producers is
given in a series of documents which outlines the approval
procedure and test requirements to qualify for inclusion in the
list of LR-Type Approved Products.

LR-Type Approval System Procedure—describes system
operation.
LR-Type Approval System Test Specification No. 2—gives
marine environmental tests.
LR-Type Approval System Test Specification No. 3—gives
certain electrical product tests.
LR-Type Approval System Test Specification No. 4—gives
internal combustion engine tests.

List of Type Approved Products 1992—Includes details of
all products currently Type Approved in accordance with the
published Type Approval System. Available in four parts:
Part 1—Marine, Offshore and Industrial Equipment
Part 2—Electrical Equipment (Environmentally Tested)
Part 3—Control Equipment (Environmentally Tested)
Part 4—Fire Protection and Fire Fighting

List of Approved Type Tested Fuses (2nd Edition, 1987 plus
Addendum 1991)—Each entry in this publication carries
information essential in the selection of fuses for marine
installations and includes details of current ratings, together
with descriptions of fuse holders and bases.

List of Approved Type Tested Circuit Breakers (2nd Edi-
tion, 1987 plus Addendum 1991)—This publication has been
developed to assist in the selection of circuit breakers in
relation to their performance under short circuit conditions.

Approved Prefabrication Primers, Recognized Corrosion
Control Coatings, Accepted Fire Safe Paints 1992—This pub-
lication consists of two main sections covering prefabrication
primers and coatings approved for corrosion control in ships’
tanks. An additional section gives useful notes on procedures
for applying tank coatings. The publication lists approximately
400 products indexed under the name of the manufacturer.

List of Approved Welding Consumables for use in Ship
Construction 1992—This document, which is published annu-
ally, lists those welding consumables that have complied with
the approval requirements for use in ship construction set out
in LR’s rules. The document lists approximately 3500 consum-
ables in seven sections related to welding process and parent
material.

5.5.2.4 Approved Manufacturer:
List of Approved Manufacturers of Materials, Recognized
Proving Establishments and Class 1 Welding Firms 1992—
Also includes a list of manufacturers of steel, castings, forg-
ings, chain cable, wire ropes, and so forth.

5.5.2.5 Computer Data:
Rulefinder

5.6 Nippon Kaiji Kyokai (Class NK)—English Publications
5.6.1 For current prices and information concerning publi-
cations:

Nippon Kaiji Kyokai (Class NK)
4-7, Kioi-Cho, Chiyoda-Ku
Tokyo 102
Japan
Tel: (81-33) 2301201
Tlx: (781) J22975 CLASSESNK
Fax: (81-33) 2303524

Nippon Kaiji Kyokai
Regional Office for the Americas
One Parker Plaza 11th
400 Kelby Street
Fort Lee, NJ 07024
Tel: 201-944-8021
Fax: 201-944-8183

5.6.2 Nippon Kaiji Kyokai (Class NK) Publication List:
5.6.2.1 Registers—Register of Ships (1995–96) with Quar-
terly Supplements—This book contains the principal particu-
lar and survey records of NK-classed ships.

5.6.2.2 Rules and Regulations/Guidances:

Regulations for the Classification and Registry of Ships (1997)
Conditions of Service for Classification of Ships and Registra-
tion of Installations (1997)
Regulations for the Issue of Statutory Certificates (1997)
Rules for Approval of Manufacturers (1997)
Rules for the Survey and Construction of Steel Ships
Part B—Class Surveys (1997)
Part C—Hull Construction and Equipment (1997)
Part U—Intact Stability (1997)
Part V—Load Lines (1997)
Part CS—Hull Construction and Equipment of Small Ships (1997)
Part D—Machinery Installations (1997)
Part H—Electrical Installations (1995)
Part K—Materials (1997)
Part L—Equipment (1997)
Part M—Welding (1997)
Part N—Ships Carrying Liquefied Gases in Bulk (1997)
Part P—Mobile Offshore Drilling Units, Workshops, and Special Purpose Barges (1997)
Part Q—Steel Barges (1997)
Part T—Submersibles (1997)
Rules for Installations of Ships
Rules for the Safety Equipment (1997)
Rules for the Radio Installation (1997)
Rules for Cargo Refrigerating Installations (1997)
Rules for Cargo Handling Appliances (1997)
Rules for Construction and Certification of Freight Containers (1994)
Rules for Floating Docks (1994)
Rules for High Speed Craft (1996)
Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use (1997)
List of Approved Materials and Equipment (1997)

5.6.2.3 Other Publications
New Shipbuilding in Japan (issued quarterly)
Class NK Technical Bulletin Directory
Annual Report
Class NK Magazine

6. Keywords
6.1 commercial shipbuilding; marine technology; ship construction; shipbuilding; shipbuilding standards; ships

### TABLE 1 Standards and Publications

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<td>Hose and Hose Assemblies for Marine Applications</td>
<td>46 CFR 28.405</td>
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<td>ANSI ASME B1.1</td>
<td>Unified Inch Screw Threads (UN and UNR Thread Form)</td>
<td>46 CFR 56.60-1, 56.25-20; TSGS</td>
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<td>ANSI ASME B1.20</td>
<td>Pipe Threads, General Purpose (Inch)</td>
<td>46 CFR 56.60-1</td>
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<td>ANSI ASME B1.20</td>
<td>Dryseal Pipe Threads (Inch)</td>
<td>46 CFR 56.60-1</td>
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<td>Pipe Threads</td>
<td>46 CFR 56.60-1</td>
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<td>Specification for General Requirements for Steel Plates for Pressure Vessels</td>
<td>46 CFR 154.1; 154.610</td>
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<tr>
<td>ASTM A 27/A 27M</td>
<td>Specification for Steel Castings, Carbon, for General Application</td>
<td>46 CFR 160.032-1; TSGS</td>
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<td>ASTM A 36/A 36M</td>
<td>Specification for Carbon Structural Steel</td>
<td>46 CFR 156.30-10; 160.035-1; TSGS</td>
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<td>Specification for General Requirements for Steel Plates for Pressure Vessels</td>
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<td>Specification for Ferritic Malleable Iron Castings</td>
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<td>Specification for Ferritic Malleable Iron Castings (Metric)</td>
<td>46 CFR 56.60-1</td>
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<td>ASTM A 216/A 216M</td>
<td>Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service</td>
<td>46 CFR 160.032-1; TSGS</td>
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<tr>
<td>ASTM A 276</td>
<td>Specification for Stainless Steel Bars and Shapes</td>
<td>46 CFR 56.60-2; TSGS</td>
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<td>ASTM A 307</td>
<td>Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength</td>
<td>46 CFR 56.25-20; TSGS</td>
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<td>ASTM A 320/A 320M</td>
<td>Specification for Alloy/Steel Bolting Materials for Low-Temperature Service</td>
<td>46 CFR 56.50-105</td>
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<td>ASTM A 370</td>
<td>Test Method and Definitions for Mechanical Testing of Steel Products</td>
<td>46 CFR 54.25-20</td>
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<td>ASTM A 525</td>
<td>Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process</td>
<td>46 CFR 160.035-1</td>
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<td>ASTM A 525M</td>
<td>Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process (Metric)</td>
<td>46 CFR 160.035-1</td>
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<td>Specification for Steel Bars, Carbon, Merchant Quality, M-Grades</td>
<td>46 CFR 56.60-2</td>
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<td>ASTM A 690</td>
<td>Specification for High-Strength Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environment</td>
<td>46 CFR 56.60-2</td>
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<td>Specification for Steam or Valve Bronze Castings</td>
<td>46 CFR 162.014-1</td>
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**Group 3 Hull Structure**

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<td>Life Preserver, Fibrous Glass, Adult and Child (Jacket Type)</td>
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<td>USCG Dwg. No. 160.009</td>
<td>Cork and Balsa Wood Ring Life Buoy; Arrangement and Construction Details</td>
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<td>USCG Dwg. No. 160.013-1</td>
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<td>Rectangular Balsa Wood Life Float with Platform, Net and Rigging</td>
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<td>USCG Dwg. No. 160.043-1(b)</td>
<td>Jackknife (with Can Opener)</td>
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<td>Color: Universal Language and Dictionary of Names</td>
<td>46 CFR 160.010-1; 160.021-1; 160.022-1; 160.024-1; 160.036-1; 160.037-1; 160.057-1; 160.171-3; 160.174-3; 160.176-9; 169.115; 169.176-8; 169.176-13</td>
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#### Group 9 Heating, Ventilation, and Air Conditioning

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ABS—American Bureau of Shipping
BV—Bureau Veritas
DNV—Det Norske Veritas
GL—Germanischer Lloyd
LR—Lloyd’s Register
NK—Nippon Kaiji Kyokai
SOLAS—Safety of Life at Sea
MARPOL—International Convention for the Prevention of Pollution from Ships

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Designation: F 1548 − 01

An American National Standard

Standard Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings Used in Piping Applications

This standard is issued under the fixed designation F 1548; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification defines classification, materials, test requirements, inspection certification, marking and packaging of fittings for use with gasketed mechanical couplings complying to Specification F 1476.

2. Referenced Documents

2.1 ASTM Standards:

NOTE 1—See Table 1 for equivalency listing of applicable, equivalent specifications.

A 47 Specification for Ferritic Malleable Iron Castings
A 48 Specification for Gray Iron Castings
A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 216 Specification for Steel Castings, Carbon Suitable for Fusion Welding for High-Temperature Service
A 234 Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
A 312 Specification for Seamless and Welded Austenitic Stainless Steel Pipe
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
A 403 Specification for Wrought Austenitic Stainless Steel Piping Fittings
A 536 Specification for Ductile Iron Castings
B 26 Specification for Alumina-Silicon-Bronze Castings
B 75 Specification for Forged and Cast Ductile Iron
B 210 Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
B 369 Specification for Copper-Nickel Alloy Castings
B 580 Specification for Anodic Oxide Coatings on Aluminum
B 584 Specification for Copper-Alloy Sand Castings for General Applications
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel

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2.2 ANSI Standards:
B 36.10 Welded and Seamless Wrought Steel Pipe
B 36.19 Stainless Steel Pipe
Z 540.1 Calibration Laboratories in Measuring Test Equipment

2.3 ANSI/AWWA Standards:
C 151/A21.51 Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water and Other Liquids
C 606-87 Grooved and Shouldered Joints

2.4 British Standards:
BS 729 Specification for Hot Dip Galvanized Coatings on Iron and Steel Articles
BS 1400 Specification for Copper Alloy Ingots and Copper Alloy and High Conductivity Copper Castings
BS 1452 Specification for Flake Graphite Cast Iron
BS 1471 Specification for Flake Graphite Cast Iron
BS 1490 Specification for Aluminium and Aluminum Alloy Ingots and Castings for General Engineering Purposes—Drawn Tube
BS 1490 Specification for Aluminum and Aluminum Alloy Ingots and Castings for General Engineering Purposes
BS 1640 Pt. 1 Wrought Carbon and Ferritic Alloy Steel Fittings
BS 1640 Pt. 2 Wrought and Cast Austenitic Alloy Steel—Nickel Steel Fittings
BS 1706 Method for Specifying Electroplated Coatings of Zinc and Cadmium on Iron and Steel
BS 2871 Specification for Copper and Copper Alloys—Tubes
BS 3071 Specification for Nickel—Copper Alloy Castings
BS 3100 Specification for Steel Castings for General Engineering Purposes
BS 3600 Specification for Dimensions of Steel Pipe for the Petroleum Industry
BS 3601 Specification for Carbon Steel Pipes and Tubes with Specified Room Temperature Properties for Pressure Purposes
BS 3605 Austenitic Stainless Steel Pipes and Tubes for Pressure Purposes
BS 4772 Specification for Ductile Iron Pipes and Fittings
BS 5781 Measurement and Calibration System
BS 6681 Specification for Malleable Cast Iron

2.5 International Standards Organization:
209 Composition of Wrought Products of Aluminum and Aluminum Alloys . . . Chemical Composition (Percent)
1459 Metallic Coatings—Protection Against Corrosion by Hot Dip Galvanizing—Guiding Principles
1460 Metallic Coatings—Hot Dipped Galvanized Coatings on Ferrous Materials—Determination of the Mass Per Unit Area—Gravimetric Method
1461 Metallic Coatings—Hot Dipped Galvanized Coatings on Fabricated Ferrous Products—Requirements
2081 Metallic Coatings—Electroplated Coatings of Zinc on Iron or Steel
2531 Ductile Iron Pipes, Fittings and Accessories for Pressure Pipe Lines
3522 Cast Aluminum Alloys—Chemical Composition and Mechanical Properties
4179 Ductile Iron Pipes for Pressure and Non-Pressure Pipelines—Centrifugal Cement Mortar Lining—General Requirements
4200 Plain End Steel Tubes, Welded and Seamless—General Tables of Dimensions and Masses Per Unit Length
5922 Malleable Cast Iron
7722 Aluminum Alloy Castings Produced by Gravity, Sand, or Chill Casting, or by Related Processes—General Conditions for Inspection and Delivery
8179 Ductile Iron Pipes—External Zinc Coating

3. Terminology
3.1 Definitions:
3.1.1 fabricated fitting—a fitting constructed by welding together sections of pipe or tube.
3.1.2 fitting—a device used in a piping system to change pipe direction, size, split or combine flows, or adapt to other joining methods.
3.1.3 grooved end—type of fitting or pipe end having a groove for use with grooved mechanical couplings (Type I) as defined in F 1476.
3.1.4 pipe—hollow tubular product conforming to Table 1 Specification Reference Nos. 19, 20, 22 and 13, Nominal Dimensions, or O.D. tube.
3.1.5 plain end—type of fitting or pipe end for use with a gasketed mechanical coupling (Type II) that is plain end as defined in Specification F 1476.
3.1.6 tangent—a section of straight pipe or tube integral to or welded to the end(s) of a fitting.
3.1.7 wrought fitting—a fitting made by shaping or shaping and welding.

4. Classification
4.1 These fittings are classified into the following design types:
4.1.1 Type I—Grooved end.
4.1.2 Type II—Plain end.

5. Ordering Information
5.1 Orders for fittings under this specification shall include the following:
5.1.1 Specification designation, title, number and year of issue.
5.1.2 Quantity.
5.1.3 Size and appropriate suffix (Example 8 in. IPS, 76.1 mm O.D.).
5.1.4 Fitting description (90° Elbow, Tee, Cross, etc.).
5.1.5 Type (I, II)—Type I must include groove style (that is, Standard, End Seal,\textsuperscript{12} AWWA Rigid, AWWA Flexible, or Copper).

5.1.6 Minimum pressure rating.

5.1.7 Material (ductile iron or steel, aluminum, copper nickel, copper, other, etc.) (see Section 6).

5.1.8 Finish (painted, galvanized, bare, plated, special coatings) (see Section 6).

5.1.9 Other requirements agreed to between purchaser and fitting manufacturer.

6. Materials and Manufacture

6.1 Ferrous Materials—Cast fittings shall be constructed of ductile iron in accordance with Table 1 Specification Reference 8 or 10 Grades 65–45–15 or 65–45–12 respectively or Malleable Iron in accordance with Table 1 Specification Reference 1 or steel in accordance with Table 1 Specification Reference 5 or Cast Iron in accordance with Table 1 Specification Reference 2. Wrought fittings shall be made in accordance with Table 1 Specification Reference 6. Fabricated fittings and tangents shall be constructed of steel in accordance with Table 1 Specification Reference 3.

6.1.1 Fitting shall be bare, coated with manufacturer’s standard preparation and paint, hot-dip galvanized in accordance with Table 1 Specification Reference 4 or other finish as agreed upon between purchaser and manufacturer.

6.2 Aluminum Alloy Materials—Fittings shall be constructed of aluminum alloy in accordance with Table 1 Specification Reference 12. Fabricated fittings shall be made from pipe in accordance with Table 1 Specification Reference 14.

6.2.1 Finish for aluminum alloy fittings shall be bare, anodized in accordance with Table 1 Specification Reference 16 or as otherwise agreed between purchaser and manufacturer.

6.3 Iron-Chromium-Nickel, Corrosion Resistance Materials—Fittings shall be constructed of iron-chromium-nickel alloy in accordance with Table 1 Specification Reference 11, or Table 1 Specification Reference 9. Welded tangents and fabricated fittings shall be in accordance with Table 1 Specification Reference 7.

6.3.1 Finish for iron-chromium-nickel shall be bare or as otherwise agreed between purchaser and manufacturer.

6.4 Copper or brass, cast fittings shall be constructed of brass in accordance with Table 1 Specification Reference 17. Wrought fittings shall be constructed of copper in accordance with Table 1 Specification Reference 13.

6.4.1 Finish for copper or brass fittings shall be bare or as otherwise agreed between purchaser and manufacturer.

6.5 Copper-nickel cast fittings shall be constructed of copper-nickel in accordance with Table 1 Specification Reference 15 as applicable.

6.5.1 Finish for copper-nickel fittings shall be bare or as otherwise agreed between purchaser and manufacturer.

6.6 Other Materials—Where other materials are required, the material, mechanical properties and finish of the products shall be as agreed upon by the fitting manufacturer and the purchaser.

6.7 Material Quality:

6.7.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics to meet the performance requirements of this standard.

6.7.2 The manufacturer is encouraged to use materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term “recovered materials” means: “Materials which have been collected or recovered from solid waste and reprocessed to become a source of raw material, as opposed to virgin raw materials.” Used or rebuilt products shall not be used.

7. Other Requirements

7.1 Design Requirements:

7.1.1 The design of the fittings may be qualified by mathematical analysis in accordance with piping codes agreed to by manufacturer and purchaser or by testing. Fittings that are tested shall be tested with gasketed mechanical couplings in accordance with the test requirements of Specification F 1476.

7.2 Qualification Requirements:

7.2.1 Mathematical Analysis:

7.2.1.1 A mathematical analysis, where appropriate, shall be performed as required by the governing piping code. Records of the analysis shall be available at the manufacturer’s facility for inspection by the purchaser.

7.2.2 Test:

7.2.2.1 The fittings shall be tested, where appropriate, with gasketed mechanical couplings in accordance with the requirements of Specification F 1476. Unless otherwise noted herein, all requirements of Specification F 1476 apply. Records of successful tests shall be available at the manufacturer’s facility for inspection by the purchaser.

7.2.3 Each type, pressure class, and material of fitting offered for sale must be qualified. Interpolation between qualified sizes is allowed as defined in Specification F 1476. Qualification of the fitting requires successful completion of the analysis or required testing. Each fitting design is only qualified for use with the GMC design on which it was tested or analyzed.

8. Dimensions, Mass and Permissible Variations

8.1 Fitting Dimensions—Fitting dimensions and tolerance shall be as specified by the manufacturer.

9. Workmanship, Finish and Appearance

9.1 All fitting surfaces shall be free from scale, blisters, fins, folds, seams, laps, burrs and cracks, which would affect the suitability for the intended service.

10. Inspection

10.1 Terms of Inspection:

10.1.1 Inspection of the fittings shall be in accordance with the manufacturer’s standard inspection procedure or as agreed upon between the purchaser and the manufacturer or supplier as part of the purchase contract.

10.2 Raw Material Inspection:

10.2.1 Raw material shall be inspected for compliance with its material specification.

10.3 Quality Conformance Inspection:

\textsuperscript{12} End seal is a registered trademark of the Victaulic Company of America.
10.3.1 Fitting samples shall be visually and dimensionally examined to verify compliance with the manufacturer’s appropriate drawings.

10.4 Process Control Inspection:

10.4.1 Fittings shall be inspected throughout the entire manufacturing and processing cycle. Methods of inspection shall be in compliance with manufacturer’s quality assurance procedures.

10.5 Inspection Records:

10.5.1 Inspection records shall be maintained by the manufacturer. The length of time on file shall be in accordance with the manufacturer’s quality assurance procedures.

11. Certification

11.1 Material Certification:

11.1.1 A certification of compliance shall be obtained from the materials supplier, when applicable. This certificate shall state that applicable requirements for the raw material have been satisfied.

12. Product Markings

12.1 Each fitting shall be marked with the manufacturer’s name or trademark, size, and markings traceable to the material and pressure rating.

13. Packaging

13.1 The fitting shall be boxed, crated, wrapped and otherwise protected during shipment and storage in accordance with manufacturer’s standard practice. Care shall be taken to properly protect the fitting from damage during shipment and storage.

14. Keywords

14.1 fitting; grooved; marine; ship; tangent
Standard Specification for Pressure-Reducing Valves for Steam Service

This standard is issued under the fixed designation F 1565; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers self-contained, internally operated, globe style, pressure-reducing valves for use in steam service. In these valves, the downstream pressure feedback is sensed by a spring-loaded diaphragm to position a pilot valve—the pilot valve uses the inlet steam pressure to position the main valve plug via an operating piston.

2. Referenced Documents

2.1 ASTM Standards:
A 105/A 105M Specification for Carbon Steel Forgings for Piping Applications
A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate-and Higher-Temperature Service
A 516/A 516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
A 547 Specification for Steel Wire, Alloy, Cold-Heading Quality, for Hexagon-Head Bolts

2.2 American Society of Mechanical Engineers (ASME) Standards:
B1.1 Unified Screw Threads
B16.5 Pipe Flanges and Flanged Fittings
B16.34 Valves—Flanged, Threaded, and Welding End
B18.2.1 Square and Hex bolts and Screws, Including Askew Head bolts, Hex Cap Screws, and Lag Screws

2.3 Federal Specification:
FED-STD-H 28 Screw-Thread Standards for Federal Services

2.4 Military Standards and Specifications:
MIL-V-3 Valves, Fittings, and Flanges (Except for Systems Indicated Herein); Packaging of
MIL-S-901 Shock Tests, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for
MIL-R-2765 Rubber Sheet Strip, Extruded, and Molded Shapes, Synthetic, Oil Resistant
MIL-P-15024 Plates, Tags and Bands for Identification of Equipment
MIL-P-15024/5 Plates, Identification
MIL-R-17131 Rods and Powders, Welding, Surfacing
MIL-G-24716 Gaskets, Metallic-Flexible Graphite, Spiral Wound
MIL-I-45208 Inspection Systems Requirements
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
NAVSEA T9074–AQ-53/200 Nondestructive Testing Requirements for Metals
NAVSEA S9073–AR龚53/2078 Fabrication Welding and Inspections and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels in Ships of the United States Navy
MIL-STD-798 Nondestructive Testing, Welding, Quality Control, Material Control and Identification and Hi-Shock Test Requirements for Piping System Components for Naval Shipboard Use

2 Annual Book of ASTM Standards, Vol 01.01.
3 Annual Book of ASTM Standards, Vol 01.02.
5 Discontinued. See 1990 Annual Book of ASTM Standards, Vol 01.03.
7 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
3. Terminology

3.1 **accuracy of regulation**—the amount by which the downstream pressure may vary when the valve is set at any pressure within the required set pressure limit and is subjected to any combination of inlet pressure, flow demand, and ambient temperature variations, within the specified limits.

3.2 **design pressure and temperature**—the maximum pressure and temperature the valve should be subjected to under any condition. These are the pressure and temperature upon which the strength of the pressure-containing envelope is based.

3.3 **hydrostatic test pressure**—the maximum test pressure that the valve is required to withstand without damage. Valve operation is not required during application of this test pressure, but after the pressure has been removed, the valve must meet all performance requirements.

3.4 **lockup pressure**—the outlet pressure delivered by a pressure-reducing valve under shutoff conditions (that is, when the flow demand is reduced to a point where it is equal to or less than the allowable leakage as defined in 8.3).

3.5 **nominal pressure**—the approximate maximum pressure to which the valve will be subjected in service under normal conditions.

3.6 **set pressure**—the downstream pressure which the valve is set to maintain under a given set of operating conditions (that is, inlet pressure and flow). Ideally, the valve should be set at downstream pressure approximately equal to the mid-point of the set pressure limits (defined in 3.7).

3.7 **set pressure limits (range of set pressure adjustment)**—The range of set pressure over which the valve can be adjusted while meeting the specified performance requirements.

4. Classification

4.1 Valves shall be of the following compositions and pressure ratings, as specified (see Section 5 and 6.1.7). The pressure-temperature ratings shown below are applicable to the pressure-containing components of the valve. See Fig. 1 and Fig. 2.

4.1.1 **Composition B**—1¼ % chromium, ½ % molybdenum [maximum temperature 1000°F (see 6.1.7)].

4.1.2 **Composition D**—carbon steel [maximum temperature 775°F (see 6.1.7)].

4.3 **Pressure Ratings**—These shall conform to ASME Class 150, Class 300, Class 600, or Class 1500.

5. Ordering Information

5.1 Ordering documentation for valves under this specification shall include the following information, as required, to describe the equipment adequately.

5.1.1 ASTM designation and year of issue.

5.1.2 Valve specification code (see 6.1.14).

5.1.3 Composition and pressure rating required (see Section 4).

5.1.4 Trim materials where specific requirement is known (see Table 1, Footnote B, Note 2).

5.1.5 Whether internal or external reduced pressure sensing line is required (see 6.1.2.1).

5.1.6 Accuracy of regulation required if other than listed in 7.2.

5.1.7 Minimum and maximum inlet steam pressures (psig) (see 7.3 and S1.5).

5.1.8 Maximum inlet steam temperature (°F) (see S1.5).

5.1.9 Range of set pressure adjustment for valves, if other than listed in 7.4.

5.1.10 Maximum and minimum capacity required lb/hour.

5.1.11 Special tools, if required (see 6.1.15).

5.1.12 Supplementary requirements, if any (see S1 through S4).

6. Valve Construction and Coding

6.1 Valves shall incorporate the design features specified in 6.1.1-6.1.14.

6.1.1 **Materials of Construction**—Materials shall be as specified in Table 1. All materials shall be selected to prevent corrosion, galling, seizing, and excessive wear or erosion where applicable. Clearances shall prevent interference as a result of the thermal expansion. Cadmium plating is prohibited.
6.1.2 General Requirements:

6.1.2.1 Valves will be operated, maintained, and repaired on board ships and shall emphasize simplicity, maintainability, ruggedness, and reliability. Design shall permit access for adjustment and repair when working from either side of the valve and without requiring removal of the valve body from the line. Valves shall be of the self-contained, internal-operated type as described in 1.1.

6.1.2.2 The operating piston shall be separate from the main valve and fitted with one or more piston rings. The design shall prevent water buildup on the piston. The piston shall operate within a separate hardened steel cylinder liner located in the valve body so that removal of the valve bonnet provides access to the top of the piston assembly. The cylinder liner shall be held in place by way of the bonnet bolting or shall be permanently fabricated into the body. The requirement to locate the cylinder liner in the body may be waived where it is shown that an alternative location provides a satisfactory maintenance configuration. Pilot valve and diaphragm chambers shall be self-draining. The pilot valve shall be single seated with integral stem. The valve shall be controlled by a spring-referenced metal diaphragm and shall open against high pressure. A return spring shall keep the pilot valve in contact with the diaphragm at all times. The diaphragm shall not travel through center during any phase of operation. Edges contacting the diaphragm shall be rounded to prevent wear and damage. The diaphragm shall not travel against high temperature of the spring. A return spring shall keep the pilot valve in contact with the diaphragm at all times. The diaphragm shall not travel through center during any phase of operation. Edges contacting the diaphragm shall be rounded to prevent wear and damage. The diaphragm shall not travel against high pressure.

TABLE 1 List of Material

<table>
<thead>
<tr>
<th>Name of Parts</th>
<th>Composition B</th>
<th>Composition D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body, bonnet, and bottom cover*</td>
<td>ASTM A 182/A 182M, Grade F 11</td>
<td>ASTM A 105/A 105M, Grade F 22</td>
</tr>
<tr>
<td></td>
<td>ASTM A 217/A 217M, Grade WCB, ASTM A 515/A 515M, A 516/A 516M, A 547</td>
<td>ASTM A 216/A 216M, Grade WCB, ASTM A 515/A 515M, A 516/A 516M, A 547</td>
</tr>
<tr>
<td>Internal trim</td>
<td>400 series CRES</td>
<td>400 series CRES</td>
</tr>
<tr>
<td>Cylinder liner and piston</td>
<td>500 Brinell min hard</td>
<td>500 Brinell min hard</td>
</tr>
<tr>
<td>Gaskets</td>
<td>MIL-G-24716, Class B</td>
<td>MIL-G-24716, Class B</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>Ni-Cr alloy</td>
<td>Ni-Cr alloy</td>
</tr>
<tr>
<td>Springs</td>
<td>300 series CRES</td>
<td>300 series CRES</td>
</tr>
<tr>
<td>Bolting*</td>
<td>ASTM A 193/A 193M, Grade B7</td>
<td>ASTM A 193/A 193M, Grade B7</td>
</tr>
<tr>
<td></td>
<td>ASTM A 194/A 194M, Grade 2H</td>
<td>ASTM A 194/A 194M, Grade 2H</td>
</tr>
</tbody>
</table>

*If desired by the manufacturer, the higher grade bolting materials may be used in lower temperature categories (for example, Specification A 194/A 194M, Grade 4 may be used for Composition B, and so forth) and also higher grade body materials for Composition B and D valves (for example, Specification A 182/A 182M, Grade F 22 for Composition B, and so forth).

**Trim materials—Unless otherwise specified (see 5.1), the valve manufacturer shall select from the categories listed below the trim materials best suited to meet the requirements.

1. Main valve trim materials. Main valve trim (defined as consisting of the seat or seat ring and plug and the guide posts and bushings) materials shall be selected from the following:
   a) Stellite—Trim to be Stellite.
   b) Hardened corrosion-resistant steel—Hardened corrosion-resistant steel plug (400 series or 17-4 PH) and Stellite seat or seat ring. Guiding surfaces to be hardened corrosion-resistant steel or Stellite.
   c) Where Stellite is used, it shall consist of either wrought Stellite 6B, cast Stellite 6, or an inlay of Stellite (not less than %2-in. thickness for main seat and disk surfaces). Where inlays are used, welding rods shall be in accordance with Type MIL-RCr-A or MIL-R-17131.

2. Pilot valve trim materials. Pilot valve trim (defined as consisting of the seat, valve, and guiding surfaces) shall be made from one or a combination of the following materials:
   a) 400 series or 17-4PH corrosion-resistant steel-hardened.
   b) Stellite.
   c) Spring materials—Where the working temperature of the spring will exceed 600°F, either Inconel X-750 or A-286 alloy steel shall be used. Where the working temperature of the spring exceeds 450°F but not 600°F, Inconel 600 or tungsten tool steel may also be used. Where the working temperature of the spring will not exceed 450°F, 300 series corrosion-resistant steel may be used.

Note 1—Pictorial representations are for illustrative purpose only and do not imply design.

FIG. 2 Pressure-Reducing Valve (Internal Pressure Sensing)
design shall permit accomplishment of the following maintenance actions within the time limits specified:

<table>
<thead>
<tr>
<th>Action</th>
<th>Time Allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disassemble, replace pilot assembly, reassemble</td>
<td>½ h</td>
</tr>
<tr>
<td>Renew pilot valve assembly trim</td>
<td>½ h</td>
</tr>
<tr>
<td>Renew main valve trim</td>
<td>¾ h</td>
</tr>
</tbody>
</table>

6.1.4 **Interchangeability**—Valve design shall permit interchangeability without individual modification of like parts between all valves. Each part shall have part number identity and shall be replaceable from stock or the manufacturer on a nonselective and random basis. With the exception of matched parts, parts having the same manufacturer’s part number shall be directly interchangeable with each other with respect to installation (physical) and performance (function). Physically interchangeable assemblies, components, and parts are those that are capable of being readily installed, removed, or replaced without alteration, misalignment, or damage to parts being installed or to adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.1.5 **Springs**—Springs shall not be fully compressed during any normal operation or adjustment of the valve. The working stress shall be such that relaxation shall not exceed 5% over a 1000-h period at the nominal operating temperature. Spring ends shall be squared and ground.

6.1.6 **Threads**—Threads shall conform to ASME B1.1. Where necessary, provisions shall be incorporated to prevent accidental loosening of threaded parts. Pipe threads shall not be used. ASME B18.2.1 hex-head standards shall be used.

6.1.7 **Pressure-Temperature Ratings**—Valve pressure-temperature rating shall be in accordance with ASME B16.34 except for maximum allowable temperature. Maximum temperature limitations shall be as follows:

- **6.1.7.1 Composition B**—1000°F.
- **6.1.7.2 Composition D**—775°F.

6.1.8 **End Preparation**—Valves shall be furnished with flanged ends in accordance with ASME B16.5. Flanges shall be cast or forged integral with the valve body, and the inlet and outlet flanges shall be of the same size and pressure rating.

6.1.9 **Bonnet and Bottom Cover Joints**—Bonnet and bottom cover (where applicable) shall be flanged for attachment to the body. Joints shall be secured by either of the following:

- (a) Through-bolts or studs threaded the entire length and fitted with a nut on each end. Threads on bolts, studs, and nuts shall be Class 2 fit in accordance with ASME B1.1.
- (b) Studs with interference fit at the tap end sufficient to preclude inadvertent backing out and a Class 2 fit at the nut end.

Bonnet and bottom cover shall be located by body guiding (that is, a close tolerance fit between machined diameters on the body, bonnet, and bottom cover) rather than depending on studs or bolts for location. Spiral wound gaskets shall be fully retained, and the joints shall have metal-to-metal take-up to provide controlled compression of the gaskets. To assure easy gasket removal, not more than two gasket-retaining faces for each gasket shall be formed on a single part. Joint design shall assure parallel alignment of the guide bushings. Sufficient bolting area shall be provided to maintain metal-to-metal make-up over at least a three-year period. Bearing surface of nuts and their respective surfaces on the valve shall be finished machined.

6.1.10 **Body Construction**—Valve bodies shall be machined from a one-piece casting or forging and shall be of basic globe configurations with in-line inlet and outlet ports. Steam lines, except for the external downstream pressure sensing line (where used), shall be internally ported in the body and bonnet. Body passages shall produce gradual changes in flow direction so as to reduce any effects of concentrated impingement and 90° turns. In portions of the valve subject to velocity increases and flow direction changes, such as immediately downstream of the seat, the design shall eliminate direct impingement against the walls at close range.

6.1.11 **Control Connections**—Where external downstream sensing is used, a ½-in. iron pipe size (i.p.s.) flanged connection, which is either cast or forged integral with the body or bonnet or welded, shall be provided.

6.1.12 **Internal Trim**—Internal trim (except welded or brazed-in seat rings) shall be readily replaceable without requiring removal of the valve body from the line. The main plug or disk shall be single seated. Guiding of the plug or disk shall prevent binding or seizing and ensure proper seating under all design conditions. This requirement shall be maintained with interchangeable parts and under any tolerance stack-up condition.

6.1.13 **Set Point Adjustment**—Means shall be provided for adjusting the set point through the specified range, with the valve under pressure. The adjusting or loading device shall be safeguarded against accidental change in set point.

6.1.14 **Valve Specification Coding**—Basic valve design features shall be specified and recorded using the following valve coding system. The valve specification code contains four fields of information, which describe the construction features of the valve. Each of these four fields are further assigned their respective codes per Tables 2-5.

6.1.15 **Maintainability**—Maintenance shall require standard tools to the maximum extent possible. Any special tools, which are not commercially available, required for adjustment or repair shall be identified and shall be supplied as part of the valve, if specified in the ordering information (see Section 5).

7. **Performance**

7.1 All valves shall meet the requirements of 7.1.1-7.8.

7.1.1 **Springs**—Springs shall not exhibit a set in excess of 0.005 in./in. of travel. Springs shall not be fully compressed during any normal operation or adjustment of the valve. Springs shall not be fully compressed during any normal operation or adjustment of the valve. Springs shall not be fully compressed during any normal operation or adjustment of the valve. Springs shall not be fully compressed during any normal operation or adjustment of the valve.

<table>
<thead>
<tr>
<th>ASTM F 1565</th>
<th>Valve pressure-rating code (Table 2)</th>
<th>Valve composition code (Table 3)</th>
<th>Valve size code (Table 4)</th>
<th>Set pressure-range code (Table 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME 150</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASME 300</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASME 600</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASME 1500</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.2 Accuracy of Regulation—The valve shall have an accuracy of regulation (see 3.1) of ±5% or ±2 psi, whichever is greater unless otherwise specified in 5.1.

7.3 Capacity—The actual steam flow capacity required, in pounds per hour (lbs/hour), based on the minimum inlet pressure and highest reduced outlet pressure setting under which the valve will be required to operate, shall be as specified (see 5.1). The valve shall meet the specified capacity requirement, or any intermediate capacity requirements down to 10% of the specified capacity requirement, and shall operate without hunting, chattering, or excessive noise or vibration, or exceeding the accuracy of regulation specified in 7.2, under all specified operating conditions.

7.4 Range of Set Pressure Adjustment (Set Pressure Limits)—Valve shall be capable of meeting the performance requirements specified in 7.2 and 7.3 when set at any point within the required range of set pressure adjustment. Unless otherwise specified (see 5.1), valve set pressure shall be adjustable over a range specified in Table 5.

7.5 Seat Tightness—With a dead-end downstream volume not exceeding the volume represented by 100 diameters of downstream pipe, any steam leakage from the inlet to the outlet of the valve shall be limited below a value which will cause a discharge pressure buildup of 10 psi in a 1-h period.

7.6 External Leakage—There shall be no external leakage which can be detected by use of a mirrored surface (for steam) or bubble fluid (for air).

7.7 Mechanical Shock and Vibration—Valve shall meet the mechanical shock requirements defined by Grade A, Class I of MIL-S-901, the HI-shock test guidance of MIL-STD-798, and the environmental vibration requirements defined by Type I of MIL-STD-167-1 up to and including 33 Hz.

7.8 Endurance—Valves shall be capable of passing the 5-h endurance test as outlined in S1.1.6.

8. Tests Required

8.1 Each production valve shall pass the tests outlined in 8.2-8.5.

8.2 Nondestructive Tests—Nondestructive tests shall be as specified in NAVSEA S9074–AR-GIB-010/278 and in accordance with NAVSEA T9074–AQ-GIB-010/271. Acceptance criteria shall be in accordance with MIL-STD-178. This shall include RT, MT/PT, pressure, and visual testing as delineated in the above specifications.

8.3 Hydrostatic Test—Valves shall be tested in accordance with ASME B16.34. There shall be no external leakage, permanent distortion, or structural failure.

8.4 Seat Tightness Test (Dead-End Test)—Using steam or air, with an inlet pressure equal to the nominal rating, the outlet pressure in a dead-end volume representing not more than 100 diameters of the downstream pipe shall not rise more than 10 psi in a 1-h period.

8.5 External Leakage Test—Pressure containing parts shall be tested with steam or air to the maximum working pressure to check for external leakage. There shall be no external leakage which can be detected by use of a mirrored surface (for steam) or bubble fluid (for air).

9. Marking

9.1 Body Markings—The manufacturer’s name or trademark and the body material composition shall be cast or forged integral with the valve body. The size, rating, and a flow arrow shall be cast or forged integral with the valve body or die stamped on raised metal pads (1/8-in. added wall thickness minimum), or stamped on the outside diameter of the flanges.

9.2 Identification Plates—An identification plate of corrosion-resistant metal shall be attached to the valve and shall list the following:

9.2.1 Manufacturer’s name.
9.2.2 Valve specification code.
9.2.3 Set pressure range.
9.2.4 ASME pressure class rating.
9.2.5 Manufacturer’s model or part number.

10. Quality Assurance System

10.1 The manufacturer shall establish and maintain a quality assurance system that will ensure all the requirements of this specification are satisfied. This system shall also ensure that all valves will perform in a similar manner to those representative valves subjected to original testing for determination of the operating and flow characteristics.

10.2 A written description of the quality assurance system the manufacturer will use shall be available for review and acceptance by the inspection authority.

10.3 The purchaser reserves the right to witness the production tests and inspect the valves in the manufacturer’s plant to the extent specified on the purchase order.

11. Keywords

11.1 marine; ship; steam; valves
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements S1, S2, S3, or S4 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Initial Qualification Testing

S1.1 Qualification tests shall be conducted at a facility satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.1.1 through S1.1.10 and delineated in the ordering data (see outline of tests in Table 2). The tests may be conducted on representative valve sizes and pressure classes to qualify all sizes and pressure classes of valves provided the valves are of the same type and design. Evidence of prior approval of these tests is acceptable.

S1.1.1 Qualification Test Sample—A sample valve(s) shall be submitted for each pressure rating for which qualification approval is desired (for sample size(s) required for shock qualification, see S1.1.7). Qualification approval, based on the examination and test of the sample, will then apply to all sizes of that pressure rating covered by this specification (see S1.1.1.1). Cross-sectional assembly drawings of all sizes of that type and rating shall be submitted with the test valve.

S1.1.1.1 Upon specific approval by the customer, valves of other sizes may be tested. Use of only one valve size for qualification of a type and rating under this specification only applies where the test valve is representative of the basic design features of all sizes of the pressure rating for which qualification is desired. The customer reserves the right to determine what are significant variations requiring separate qualification testing.

S1.1.2 Examination Before Testing—Upon receipt of the qualification test sample, the sample valve(s) shall be disassembled and visually and dimensionally examined to determine conformance with the requirements of this specification and complete dimensional conformance to the detailed engineering drawings.

S1.1.2.1 Upon satisfactory completion of the examination specified in S1.1.2, the valve(s) shall be tested as specified in S1.1.3 through S1.1.9.

S1.1.3 Spring Test—The spring from the disassembled sample valve shall be visually and dimensionally examined as follows:

S1.1.3.1 The free spring length shall be measured and an allowance of 0.010 in. per each inch of free spring length calculated. Fraction of inches of free spring length shall be prorated and added to the calculations for allowance.

S1.1.3.2 The spring shall be compressed to its working height and released.

S1.1.3.3 Ten minutes after release, the spring shall be measured again.

S1.1.3.4 The spring shall not exhibit a set in excess of the allowance calculated in S1.1.3.1.

S1.1.4 The valve shall be subjected to and must pass the tests outlined in 8.1-8.4 (nondestructive test, hydrostatic test, seat tightness test, and external leakage test).

S1.1.5 Performance Test—The performance tests shall be conducted with the valve set at the upper, mid-point, and lower setting of the adjustable set pressure range required by the application (see 5.1). Test medium shall be steam. The maximum inlet temperature, the range of operating inlet pressures, and the maximum flow capacity required shall be as specified (see 5.1) to meet the application requirements. The required accuracy of regulation shall be maintained. There shall be no evidence of hunting, chattering, or any other unstable or unsatisfactory operation of the valve during any portion of the required operational range of the valve.

S1.1.5.1 The flow shall be varied from lock-up to the maximum flow rating of the valve and back (see 5.1). This test shall be conducted under the following sets of conditions:

- Condition (a) Max inlet pressure − lowest set pressure.
- Condition (b) Min inlet pressure − lowest set pressure.
- Condition (c) Min inlet pressure − mid-point set pressure.
- Condition (d) Max inlet pressure − mid-point set pressure.
- Condition (e) Max inlet pressure − highest set pressure.
- Condition (f) Min inlet pressure − highest set pressure.

During each group of test conditions (that is, (a) and (b), (c) and (d), and (e) and (f), no alteration shall be made to the set pressure adjustment, or any other portion of the valve. The duration of the test at each condition shall not exceed 30 s.

S1.1.6 Endurance Test—The valve shall be subjected to a 5-h operational test to check functioning and performance. Test medium shall be steam. The 5-h test shall include not less than 25-min aggregate time within each of the following specific flow ranges: 95 ± 5 % maximum rated flow; 25 ± 3 % maximum rated flow; and 10 ± 2.5 % maximum rated flow.

The valve shall operate at all times without evidence of instability, without allowing delivered pressure to vary from specified limits, and without requiring any maintenance, repair, or adjustment effort. At the successful completion of the 5-h test, the valve shall be removed and completely disassembled. All parts shall be examined for signs of excessive wear or any other condition indicating impending failure or malfunction. Any such condition shall constitute grounds for failure of the valve to pass these tests, regardless of how satisfactorily the valve performed during the 5-h test. Impending failure or malfunction is defined as one which can be expected to occur within one year of operation.

S1.1.7 Shock Test—Sample size(s) for shock qualification testing shall be in accordance with MIL-STD-798. The valve shall be subjected to the high-impact mechanical requirements for Grade A, Class I of MIL-S-901 to determine its resistance to high-impact mechanical shock. The shock test shall be performed with the nominal hydrostatic pressure applied to the inlet port. During impact, an instantaneous, reversible pressure excursion is allowable.
S1.1.8 Vibration Test—The valve shall be vibration tested in accordance with Type I of MIL-STD-167-1.
S1.1.9 Maintenance Demonstration—The maintenance actions specified in 6.1.3 shall be demonstrated.
S1.1.10 Posttest Examination—After completion of the tests specified in 8.2-8.5 and S1.1.5 through S1.1.7, the test valve shall be disassembled and visually and dimensionally examined. Any damage, excessive wear, or signs of galling or pitting shall cause for rejection.

S2. Examinations
S2.1 Lot—All valves of the same type and size offered for delivery at one time shall be considered a lot for the purpose of sampling.
S2.2 Sampling for visual and dimensional examination. A random sample of valves shall be selected from each lot as shown below and shall be examined as specified in S2.3 and S2.4. Failure of any valve in a sample to pass the examination specified in S2.3 and S2.4 shall be cause for rejection of the lot.

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 25</td>
<td>1</td>
</tr>
<tr>
<td>26 to 65</td>
<td>2</td>
</tr>
<tr>
<td>66 to 180</td>
<td>3</td>
</tr>
<tr>
<td>Over 180</td>
<td>4</td>
</tr>
</tbody>
</table>

S2.3 Visual Examination—A visual examination shall be made of the sample valves selected in accordance with S2.2 to verify conformance to the requirements of the specification.
S2.4 Dimensional Examination—A dimensional examination shall be made on the sample valves selected in accordance with S2.2 to verify conformance with the approved master drawing.

S3. Technical Data and Certification Requirements
S3.1 Drawings—Assembly drawings, information sheets, or catalog sheets of the pressure-reducing valve shall be provided to indicate the design and materials used in the valve.
S3.2 Technical Manuals—A technical manual or instruction booklet shall be supplied that provides a description of the valve, its operation and maintenance instructions, and illustrated parts breakdown. It shall also include wrench sizes and assembly torques (or equivalent) for all bolting and threaded assemblies, and step-by-step disassembly and reassembly procedures.
S3.3 Certification—Certification shall be provided indicating that the valve meets all requirements of the purchase order.

S4. Quality Assurance
S4.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.
S4.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.
S4.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.
S4.4 Review of quality assurance system. The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.
S4.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.
S4.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.
S4.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system that identifies inspection status of material throughout all stages of manufacture.
S4.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions using documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.
S4.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.
S4.10 Welding—The quality control system shall include provisions for ensuring that welding conforms to specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made available to the inspection authority if required.
S4.11 Nondestructive Examination—Provisions shall be made to use nondestructive examination as necessary to ensure that material and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer and/or qualified by a recognized national body, and their authorizations/qualification records shall be made available to the inspection authority if required.
S4.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.
S4.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.
S4.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of material during all stages of manufacture and shall be able to distinguish between inspected and non-inspected material.

S4.15 Calibration of Measurement and Test Equipment—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring and test equipment to be used in verifying conformance to the specified requirements. Such calibration shall be traceable to a national standard and calibration records shall be maintained.

S4.16 Records Maintenance—The manufacturer shall have a system for the maintenance of inspection records, radiographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S4.17 Sample Forms—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S4.18 Inspection Authority—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with originals or copies of such documents.

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Standard Specification for
Fabricated or Cast Automatic Self-Cleaning, Fuel Oil and
Lubricating Oil Strainers

This standard is issued under the fixed designation F 1567; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers automatic or continuously self-cleaning automatic strainers, or both, for use in fuel and lubrication oil systems. The strainer is designed to operate under positive pressure (discharge side of the pump). Strainers manufactured to this specification are suitable for use in any marine environment.

1.2 It is not the intent of this document to redefine existing filtration standards. The intent is to provide sound guidelines for purchasers and designers of lube oil and fuel oil systems. Nominal micron requirements and filter efficiencies shall be as agreed upon by the purchaser and manufacturer and stated in the purchase order document.

2. Referenced Documents

2.1 ASTM Standards:
- D 3951 Practice for Commercial Packaging
- F 795 Practice for Determining the Performance of a Filter Medium Employing a Single-Pass, Constant-Rate, Liquid Test
- F 1199 Specification for Cast (All Temperatures And Pressures) and Welded Pipe Line Strainers (150 psig And 150°F Maximum)
- F 1200 Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150°F)

2.2 ASME/ANSI Standards:
- ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Pressure Vessels
- ASME Boiler and Pressure Vessel Code: Section IX, Welding and Brazing Procedures

2.3 American Welding Society Standard:
- AWS D1.3 Structural Welding Code

2.4 MSS Standards:
- SP25 Standard Marking Systems for Valves and Fittings
- SP55 Quality Standards for Valve, Flanges and Fittings and Other Piping Components (Visual Method)

2.5 Federal Specification:
- PPP-F-320 Fiberboard: Corrugate and Solid Sheet Stock (Container Grade) and Cut Shapes

2.6 Military Specifications:
- MIL-P-116 Preservation, Methods of
- MIL-B-121 Barrier Material, Greaseproofed, Water Proofed, Flexible
- MIL-P-15024 Plates, Tags and Bands for Identification of Equipment
- MIL-P-15024/5 Plates, Identification

2.7 Military Standards:
- MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II Internally Induced)
- MIL-STD-740 Airborne and Structureborne Noise Measurement and Acceptance Criteria of Shipboard Equipment


B16.5 Steel Pipe Flanges and Flanged Fittings (Including Ratings for Class 150, 300, 400, 600, 900, 1500, and 2500)
B16.42 Ductile Iron Pipe Flanges and Flanged Fittings Class 150 and 300
Y14.5 Dimensioning and Tolerancing
American Welding Society Standard:
AWS D1.3 Structural Welding Code
MSS Standards:
SP25 Standard Marking Systems for Valves and Fittings
SP55 Quality Standards for Valve, Flanges and Fittings and Other Piping Components (Visual Method)
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MIL-P-15024/5 Plates, Identification
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MIL-STD-740 Airborne and Structureborne Noise Measurement and Acceptance Criteria of Shipboard Equipment

Available from Manufacture’s Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.
Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 filter, or straining element—the replaceable component in a strainer that performs the barrier separation of solid particles from flowing fluid. It shall be removable for cleaning and servicing.

3.1.2 maximum allowable working pressure (MAWP)—the highest internal pressure that the strainer can be subjected to in service. The maximum non-shock working pressure for which a strainer is rated by the manufacturer on its nameplate.

3.1.3 maximum design temperature—the maximum temperature for which a strainer is rated by the manufacturer.

3.1.4 strainer—a device which, when installed in a pipeline, provides a mechanical means of removing suspended solids from flowing liquid.

3.1.5 Straining element open area. The net effective open area of the clean element through which the fluid can pass.

4. Classification

4.1 Strainers shall be furnished as Type I fuel oil or Type II lubricating oil. The strainers may be either hydraulic, electric, or pneumatic operated.

5. Ordering Information

5.1 Orders for strainers under this specification shall include the following:

5.1.1 This specification number,

5.1.2 Operating and design requirements for flow rate, pressure, temperature, nominal micron rating, fluid type, and viscosity. ASME Section VIII Division I Code Stamp requirements.

5.1.3 Flanged end connections class and type drilling, that is, ANSI, DIN, and so forth.

5.1.4 Orientation of inlet and outlet connections (see 6.2.9).

5.1.5 Repair spare parts package (see 14.1).

5.1.6 Quality criteria and test plan requirements.

5.1.7 Additional test or supplementary requirements (that is, ship motions and attitude constraints, see 7.3 and S1).

5.1.8 Strainer element open area if greater than requirements in 6.2.6.

5.1.9 Any special seal requirements.

5.1.10 Any special control requirements, that is, differential pressure gages, valves, control panels, motors and so forth.

5.1.11 Certified drawing requirements showing maintenance envelope and mounting details.

6. Materials and Manufacture

6.1 The strainer shall be designed to remove contaminating or unwanted solid particles, or both, from fuel oil and lube oil. The self-cleaning action shall be automatic, and shall have the ability to backwash, when required, the filtered fluid through the filter element in segments such that the contaminating particles are flushed free of the filter element. The self-cleaning action of each unit shall be driven by a motor (electric, pneumatic, or hydraulic.)

6.2 Components—Each strainer assembly shall consist of a housing with a removable cover, inlet and outlet connections, filter/straining element(s), self-cleaning mechanism(s), controls, and a differential pressure gauge. The strainer unit shall have suitable supports. The cross-sectional flow area throughout the unit shall be equal to or greater than that of the piping to which the strainer is connected.

6.2.1 Housing—The strainer housing, cover, flanges, and other items which form the pressure boundary shall conform to the requirements of the ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Pressure Vessels. Cast grey iron pressure retaining components shall not be used. Units requiring ASME stamp shall have it specified in the purchase agreement. The dirty oil inlet shall be located at the lower part of the body and arranged to help prevent contamination of the clean outlet side of the strainer during disassembly.

6.2.2 Cover—The removable cover shall be secured to the housing by threaded fasteners. Removal of the cover shall provide access to all internal components and shall not require unbolting the inlet and outlet strainer piping connections. Cover lifting devices with integral supports or lifting eyes shall be required for covers weighing more than 30 lb.

6.2.2.1 Antispray feature—The strainer cover shall contain a device to deflect fluid spray downward in the event of gasket failure. The spray deflector shall remain in position at all times when the cover is connected to the housing.

6.2.3 Gasket—The gasket or o-ring shall be capable of providing a positive seal under service and test conditions. The gasket shall be installed between the cover and strainer housing. This gasket shall be in place during the hydrostatic pressure test.

6.2.4 Pipe and Flange Dimensions—The inlet and outlet flanges shall be sized and drilled to conform with ANSI B16.5, Class 150 or 300, or as specified in the ordering data (see 5.1.3 and ANSI B 16.42).

6.2.5 Element Support—The filter element support shall not permanently deform when the assembly of the filter element and element support is subjected to the strength of internals test (see 9.3.3). The element support shall be designed to facilitate easy removal of the filter element and element support as one assembly. The element support must satisfy the flow area requirements of 6.2.6.

6.2.6 Filter Element—The filter element may be furnished in any corrosion resistant material compatible with the fluid in service. The filter element shall be attached to the element support in such a manner that it can be easily removed and replaced from the element support. The straining element open area shall be at least two to four times larger than the area of the strainer discharge connection.

6.2.7 Motor—The self-cleaning action of each unit shall be operated by a motor included as a part of the strainer. This motor can be hydraulic, electric or pneumatic.

6.2.7.1 Hydraulic motor—A motor exhaust connection sized to meet the strainer hydraulic motor shall be provided. This motor exhaust connection shall also be suitable for venting air during the initial fill and pressurization.

6.2.7.2 Electric motor—Electric motors shall be fractional horsepower, TEFC, NEMA design B, with a continuous rated
1.15 service factor or equivalent. Voltage, phase and cycle rating shall be stated in the purchase document.

6.2.7.3 Pneumatic motor—Design type shall be agreed upon between the purchaser and manufacturer.

6.2.8 Backflush Structure—The backflush structure shall periodically or continuously clean all of the filter element by backflushing system fluid through the element. The structure shall clean the filter element in segments so as not to disrupt the system flow through the strainer at any time. All impurities separated shall be isolated from the filtered liquid and discharged. All shaft penetrations shall require seals suitable for oil service.

6.2.9 Connections—The inlet and outlet connections shall be flanged. The inlet and outlet shall be permanently marked and identified.

6.2.9.1 Drain connections shall be provided. These connections shall be furnished with caps or plugs.

6.2.9.2 The unit shall have a suitable means of removing sludge from the strainer when it is isolated from service or during normal operation.

6.2.10 Lifting Attachments—Each housing and the cover shall be provided with suitable sling attachment areas for lifting in a normal position. If lifting eyes are used, each eye shall have the capability to carry the total weight.

6.2.11 Mounting—Free standing strainers shall be mounted by feet attached to the housing. Each foot must be provided with a suitable hole to accommodate one hold-down bolt.

6.3 Welding—Welding for nonpressure-boundary components shall be in accordance with the AWS Structural Welding Code. Welding for pressure boundary components shall be in accordance with the ASME Boiler and Pressure Vessel Code.

6.4 Treatment and Painting—The exterior of the strainer shall be treated and painted in accordance with standard commercial practice.

6.5 Material—Ductile iron, bronze, carbon steel, and stainless steel materials used in the fabrication of the automatic self-cleaning strainer shall not affect nor be affected by petroleum products. Materials shall be in accordance with ASTM or ASME specifications. Dissimilar metal connections shall be designed to provide optimum corrosion protection.

6.6 Seals—Strainer seals shall be elastomers suitable for this service.

7. Operating Requirements

7.1 Pressure—The strainer shall be suitable for operation in the range of 0.21 to 1.03 MPa (30 to 150 psi).

7.2 Temperature—The strainer shall be suitable for operation between 15 to 120°C (60 to 250°F) unless otherwise specified in the ordering data (see 5.1.2).

7.3 Shipboard Performance—Strainers shall be capable of operating in accordance with all requirements of this specification when subjected to the purchase agreement specified ship motion and attitude constraints (see 5.1.7).

7.4 Self-Cleaning Rate—The pressure drop through the strainer assembly shall not exceed the manufacturer’s maximum rated pressure drop during operation. Specifically, the self-cleaning mechanism shall be capable of maintaining the pressure drop below this value when contaminated fluid is being pumped through the strainer at the design flow specified in 5.1.2.

8. Workmanship

8.1 Workmanship—The strainer and its components shall be free from blow holes, porosity, hard spots, shrinkage defects and cracks. All surfaces shall be smooth and clean (reference MSS SP55). Where dimensions and tolerances affect interchangeability, operation, or performance or any combination thereof, they shall be held.

8.2 Cleaning—The strainer shall be cleaned of all extraneous material and dried.

9. Tests

9.1 Each strainer will have standard hydrostatic tests performed in accordance with Specifications F 1199 or F 1200 whichever is applicable. When specified as part of the purchase agreement, a detailed test plan may be submitted for approval. The performance, prototype and operational tests listed herein, shall be performed to prove the design. All strainers produced under this specification will meet these minimum requirements. Proof of test qualification shall be provided when specified in the purchase agreement.

9.2 Test Extensions—When the following conditions are satisfied, extension of a product test of one size to qualify another size is permitted (see Table 1):

9.2.1 Similar geometry and design characteristics.

9.2.2 Similar or stronger material than the tested unit.

9.2.3 Same pressure rating.

9.2.4 Similar or stronger end connections.

9.2.5 Similar sealing configurations.

9.2.6 Same mode of operation and operator attachment.

9.3 Operational Tests:

9.3.1 Flow Capacity Test—The test shall be performed in general accordance with Practice F 795. The pressure drop at the rated flow shall not exceed 0.07 MPa (10 psi) with a fluid viscosity of 250 SSU.

9.3.2 Inclined Flow Capacity Test—The flow capacity test in 9.3.1 will be performed at a list and trim angle of 30°.

9.3.3 Strength of Internals Test:

The filter elements shall be proven to withstand a minimum pressure differential of ten times the rated clean pressure differential or ⅓ of the maximum allowable working pressure (MAWP) of the housing, whichever is greater. The increased differential pressure shall be held or maintained for 30 min. The strainer assembly will then be disassembled and inspected.

<table>
<thead>
<tr>
<th>Strainer/Filter Pipeline Size</th>
<th>Tested, mm (in.)</th>
<th>Other Sizes Approved By This Test, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 (⅞)</td>
<td>5/8 and smaller</td>
<td></td>
</tr>
<tr>
<td>50 (2)</td>
<td>35 (1⅝), 40 (1⅝), 50 (2)</td>
<td></td>
</tr>
<tr>
<td>150 (6)</td>
<td>65 (2⅓), 80 (3), 100 (4), 150 (6)</td>
<td></td>
</tr>
<tr>
<td>200 (8)</td>
<td>200 (8)</td>
<td></td>
</tr>
<tr>
<td>250 (10)</td>
<td>250 (10)</td>
<td></td>
</tr>
</tbody>
</table>

(| TABLE 1 Test Extensions |

*Above 250 mm (10 in.), test extensions methods shall be agreed upon between the purchaser and the manufacturer and should be specified in the purchase agreement.*
Any permanent deformation or signs of damage shall constitute failure of the test. When testing methods are not practical, calculations or finite element analysis methods may be used as objective evidence that the strength of internals meet the requirements. The acceptance of these methods is to be a matter of contract and will be specified in the purchase agreement.

9.4 Self-Cleaning and Filtration Efficiency Test—The test fluid shall be an SAE 40 weight lubricating oil. The liquids viscosity should be either 250 or 500 SSU. This shall be clearly stated on the test report. The test report contaminants shall be silica sand with a known granular size and distribution.

The solids loading during the test shall be increased in intervals until a maximum value of 300 PPM is reached. Test data shall be recorded for a minimum of ½ h at each PPM loading.

<table>
<thead>
<tr>
<th>PPM</th>
<th>Run Time in min</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 PPM (MG/L)</td>
<td>30</td>
</tr>
<tr>
<td>40 PPM (MG/L)</td>
<td>30</td>
</tr>
<tr>
<td>60 PPM (MG/L)</td>
<td>30</td>
</tr>
<tr>
<td>80 PPM (MG/L)</td>
<td>30</td>
</tr>
<tr>
<td>100 PPM (MG/L)</td>
<td>30</td>
</tr>
<tr>
<td>200 PPM (MG/L)</td>
<td>30</td>
</tr>
<tr>
<td>300 PPM (MG/L)</td>
<td>30</td>
</tr>
</tbody>
</table>

Practice F 795 shall be used as a guide to performance testing and the reporting of test results.

10. Inspection

10.1 Responsibility for Inspection—The contractor is responsible for the performance of all inspection requirements. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements.

10.1.1 Responsibility for Compliance—Items must meet the requirements of Sections 6, 7, and 8, and, if so ordered, those of the Supplementary Requirements (see 5.1.7). The inspections set forth in this specification shall become a part of the contractor’s inspection system or quality program. The absence of inspection requirements in the specification shall not relieve the contractor of the responsibility of assuring that products or supplies submitted for acceptance shall comply with requirements of the contract. Quality conformance sampling does not authorize submission of defective material, nor does it commit the purchaser to accept defective material.

10.1.2 Quality Conformance Inspection—Quality conformance inspection shall consist of the visual and dimensional inspections specified in 10.1.3. Quality conformance inspection shall be accomplished on 100% of the assemblies offered. Only those assemblies which pass all inspections shall be delivered to the purchaser.

10.1.3 Visual and Dimensional Inspection—The visual and dimensional inspection shall consist of the inspection listed in Table 2.

10.1.4 Design Data Inspection—The contractor shall provide the purchaser with documentation to show that the requirements of Table 2 have been satisfied. This documentation may include drawings, engineering analyses, or test data, or any combination thereof. The inspections listed in Table 3 shall be verified by engineering review of the documentation provided.

### Table 2 Visual and Dimensional Inspection

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Requirement Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of replaceable units</td>
<td>6.1, 5.1.5</td>
</tr>
<tr>
<td>Presence of ASME stamp (if part of purchase agreement)</td>
<td>6.2.1</td>
</tr>
<tr>
<td>Presence and type of cover fasteners</td>
<td>6.2.2</td>
</tr>
<tr>
<td>Access to internals without breaking inlet and outlet connections</td>
<td>6.2.2</td>
</tr>
<tr>
<td>Presence of cover lifting device, if required</td>
<td>6.2.2</td>
</tr>
<tr>
<td>Presence of antispray feature integral with cover</td>
<td>6.2.2.1</td>
</tr>
<tr>
<td>Presence, sizes, and locations of connections</td>
<td>6.2.9</td>
</tr>
<tr>
<td>Presence of required caps and plugs</td>
<td>6.2.9</td>
</tr>
<tr>
<td>Presence of lifting eyes</td>
<td>6.2.10</td>
</tr>
<tr>
<td>Presence and type of mounting feet</td>
<td>6.2.11</td>
</tr>
<tr>
<td>Presence and color of paint</td>
<td>6.4</td>
</tr>
<tr>
<td>Presence, completeness, legibility, and correctness of identification</td>
<td>11.1</td>
</tr>
<tr>
<td>Quality of workmanship</td>
<td>8.1</td>
</tr>
<tr>
<td>Presence and contents of technical publications</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3 Design Data Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
</tr>
<tr>
<td>Quality of materials</td>
</tr>
<tr>
<td>Proper selection of materials</td>
</tr>
<tr>
<td>Provisions for dissimilar metal contact, if applicable</td>
</tr>
<tr>
<td>Self-cleaning entirely automatic</td>
</tr>
<tr>
<td>Method of self-cleaning</td>
</tr>
<tr>
<td>Presence and volume of contaminant sump</td>
</tr>
<tr>
<td>Hydraulic motor(s) driven by strained system fluid exclusively</td>
</tr>
<tr>
<td>Flow area throughout strainer unit</td>
</tr>
<tr>
<td>Full flow maintained during self-cleaning</td>
</tr>
<tr>
<td>Suitability of strainer assembly for pressure and temperature</td>
</tr>
<tr>
<td>Ability of strainer assembly to withstand motions induced by shipboard use</td>
</tr>
<tr>
<td>Self-cleaning rate</td>
</tr>
<tr>
<td>Ease of access to internals</td>
</tr>
<tr>
<td>Cover removable without breaking inlet and outlet connections</td>
</tr>
<tr>
<td>Weight of cover, if lifting device not provided</td>
</tr>
<tr>
<td>Adequacy of antispray device</td>
</tr>
<tr>
<td>Gasket material</td>
</tr>
<tr>
<td>Certification that gasket was used during hydrostatic pressure test</td>
</tr>
<tr>
<td>Flange dimensions</td>
</tr>
<tr>
<td>Ease of removal of assembly of filter element and element support</td>
</tr>
<tr>
<td>Ease of removal of filter element</td>
</tr>
<tr>
<td>Flow area through assembly of filter element and element support</td>
</tr>
<tr>
<td>Selection of pressure gauge</td>
</tr>
<tr>
<td>Material of seals</td>
</tr>
<tr>
<td>Connection sizes</td>
</tr>
<tr>
<td>Strength of lifting eyes</td>
</tr>
<tr>
<td>Welding procedures</td>
</tr>
<tr>
<td>Exterior painting</td>
</tr>
</tbody>
</table>
11. Product Marking

11.1 Consult MSS SP25.

11.2 Identification—Identification plates, if required in the contract, shall be provided and shall include the following information:

11.2.1 The nominal pipe size of the inlet and outlet connections.
11.2.2 Design pressure, flow capacity.
11.2.3 The necessary operating instructions.
11.2.4 Weight when wet (operational weight).

12. Packaging

12.1 Protection—Strainer assemblies and their associated parts shall be individually preserved and packaged to afford adequate protection against corrosion, deterioration and physical damage from shipment between the supply source and the first receiving activity.

13. Supporting Documentation

13.1 Technical and Logistics Documentation—The contractor shall furnish the following publications applicable to the assemblies supplied under this specification:

13.1.1 Spare parts listing.
13.1.2 Maintenance, service, and repair manual.
13.1.3 Graph of expected pressure drop across the strainer assembly as a function of flow at various fluid viscosities. The maximum pressure drop allowed shall be indicated.
13.2 Test Report—Upon completion of the tests, a test report shall be prepared. The report shall be certified and signed by the contractor’s quality control representative.

14. Repair Parts

14.1 Repairs Parts Kit—When specified (see 5.1.5) a repair/spare parts kit shall be furnished and delivered with each assembly. The kit shall contain the parts and quantities specified in the contract.

15. Keywords

15.1 automatic self-cleaning strainers; fuel oil strainers; lubrication oil strainers; simplex strainers

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements apply only when specified by the purchaser in an order (see 5.1.7).

S1. Referenced Documents

S1.1 Government Specifications, Standards, and Handbooks—The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein.

S2. Preparation for Delivery

S2.1 Preservation—Preservation shall be Level A or industrial, as specified.
S2.1.2 Level A—Cleaning, drying and preservatives shall be in accordance with MIL-P-116. Strainer unit shall be protected by Method I of MIL-P-116.
S2.1.2.1 Strainer assembly—All internal bare metal surfaces subject to corrosion shall be preserved using a preservative compatible to the system requirements. Unless otherwise specified. See S2.1, Type P2 of MIL-P-116 shall apply.
S2.1.2.2 External bare metal surfaces—Machined surfaces and unpainted corrodbile metal surfaces shall be coated with MIL-P-116 P-2 preservative and wrapped with greaseproof barrier material conforming to Type I, Grade A of MIL-B-121.
S2.1.2.3 Preservative protection—All equipment surfaces which are preserved shall be protected from direct contact with any blocking, dunnage, and shrouding by inserting one or more layers of barrier material conforming to Type I, Grade A of MIL-B-121 at points of contact.
S2.1.2.4 Openings—The open ends of all flanges and fittings shall be coated with MIL-P-116 Type P-2 preservative and sealed with similarly preserved blind flanges or plastic plugs/caps. The ends of the flanges and fittings shall be wrapped with greaseproof barrier material conforming to Type I, Grade A of MIL-B-121.
S2.1.2.5 Technical Publications—Technical publications, which accompany shipment prepared for Level A, shall be preserved in accordance with Submethod 1C-1 or MIL-P-116 and secured to the hardware package. Technical publications shall not be placed within the sealed barrier material used to enclose the strainer assembly. Technical publications, when shipped in bulk quantities shall be preserved to MIL-P-116 Submethod 1C-1 and packed in fiberboard containers in accordance with PPP-F-320.
S2.2 Packing—Strainers preserved as specified (see S3.1), shall be packed in exterior shipping containers for the level of packing specified in accordance with Table VII, exterior shipping container requirements, of MIL-STD-2073-1, and herein.
S2.3 Caseliners, Closure, and Gross Weight:
S2.3.1 Caseliners—Unless otherwise specified, shipping containers containing strainers preserved commercial shall be provided with waterproof caseliners in accordance with MIL-STD-2073-1.
S2.3.2 Closure—Container closure, reinforcing, or banding shall be in accordance with the applicable container specification or appendix thereto except that class-weather-resistant/fire-retardant fiberboard boxes shall be closed in accordance with Method V and reinforced with nonmetallic or tape banding and class-domestic/fire-retardant fiberboard boxes shall be closed in accordance with Method I using pressure-sensitive tape.
S2.3.3 Weight—Wood, plywood, and cleated type containers exceeding 200-lb gross weight (91-kg gross mass) shall be modified by the addition of skids in accordance with MIL-STD-2073-1 and the applicable container specification or appendix thereto.

S2.4 Industrial—Items prepared for shipment shall be packaged in accordance with Practice D 3951 (see 12.1).

S2.4.1 Container Modification—Shipping containers exceeding 200-lb gross weight shall be provided with a minimum of two 3- by 4-in. nominal (75- by 100-mm) wood skids laid flat, or skid- or all-type base which will support the material and facilitate handling by mechanical handling equipment during shipment, stowage, and storage.

S2.5 Marking—In addition to any special marking required, interior (unit and intermediate) packs and shipping containers shall be marked including bar coding and structural for shipment, stowage, and storage in accordance with MIL-STD-2073-1.

S3. Data Requirements

S3.1 Data Requirements—When this specification is used in acquisition and data are required to be delivered, the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with approved Contract Data Requirements List (CDRL), incorporated into the contract. When the provision of DOD FAR Supplement, Part 27, Sub-Part 27.471-1 (DD Form 1423) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this specification are cited in the following paragraphs.

<table>
<thead>
<tr>
<th>Paragraph No.</th>
<th>Data Requirement Title</th>
<th>Applicable DID No.</th>
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<tbody>
<tr>
<td>S3.4</td>
<td>Product Drawings and Associated Lists</td>
<td>DI-DRPR-81000</td>
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<td>S4.4</td>
<td>Plan, Inspection and Test</td>
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<td>10.1.2</td>
<td>Procedures, Test</td>
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<tr>
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<td>Test/Inspection Reports</td>
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<tr>
<td>S4.2</td>
<td>First Article Qualification Test Plan</td>
<td>DI-T-5313-A</td>
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</tbody>
</table>

S3.1.1 Data item descriptions related to this specification, and identified in 5 and the Supplement will be approved and listed as such in DOD 5010.12-L, AMSDL. Copies of data item description required by contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.

S3.2 Data Requirements Waiver Instructions—The data requirements of this specification may be waived by the contracting/acquisition activity upon certification by the officer that identical data were submitted by the officer and accepted by the Government under a previous contract for an identical item acquired to this specification. This does not apply to specific data which may be required for each contract regardless of whether an identical item has been supplied previously (for example, test reports). When specified in the contract or order, a certificate of compliance shall be prepared.

S3.3 Technical Manuals—The requirement for technical manuals and technical repair standards should be considered when this specification is applied to a contract. If technical manuals are required, military specifications and standards which have been cleared and listed in DOD 5010.12-L (AMSDL) must be listed on a separate CDRL (DD Form 1423), included as an exhibit to the contract. The technical manuals must be acquired under separate contract line item in the contract.

S3.4 Drawings—Drawings shall be prepared in accordance with S3.1. One set of reproducible (or microfilm) drawings shall be furnished to the contracting agency after first article inspection approval.

S3.5 Identification—Identification plates shall be provided in accordance with MIL-P-15024 and MIL-P-15024/5, and shall include the following information:

S3.5.1 The nominal pipe size of the inlet and outlet connections.
S3.5.2 Design pressure, flow capacity.
S3.5.3 The necessary operating instructions.
S3.5.4 National Stock Number (NSN).
S3.5.5 Weight when wet (operating weight).
S3.6 Technical, Logistics Documentation—The contractor shall furnish the following publications applicable to the assemblies supplied under this specification:

S3.6.1 Spare parts listing.
S3.6.2 Maintenance, service, and repair manual.
S3.6.3 Graph of expected pressure drop across the strainer assembly as a function of flow at various fluid viscosities. The maximum pressure drop allowed shall be indicated.

S4. Inspection

S4.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

S4.1.1 First article inspection (see S4.2).
S4.1.2 Quality conformance inspection (see 10.1.2).

S4.2 First Article Inspection—First article inspection shall consist of the visual and dimensional inspections and the design data inspections specified in Section 10, and the tests specified in 9.1, in that order. The strainer assembly must pass all inspections and tests specified to be considered acceptable.

S4.3 First Article—The contractor shall furnish a sample strainer for first article inspection and test (see S4.5).

S4.4 Inspection System—An inspection system program plan shall be prepared (see S4.1).

S4.5 First Article—When a first article inspection is required, the items shall be a first article sample. The first article shall consist of the units specified. The contracting officer should include specific instructions in acquisition documents regarding arrangements for examinations, approval of first article test results and disposition of first articles.

S4.5.1 Invitations for bids should provide that the Government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired and tested by the Government, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior government approval is presently appropriate for the pending contract.

S4.6 Reliability—The contractor shall provide, with the first article, an engineering calculation of the mean time between failure for the strainer operating under the conditions specified herein.
S5. Shock, Vibration, and Acoustic Requirements

S5.1 Mechanical Shock—The strainer assembly, including the differential pressure gauges, shall meet the high impact shock requirements of MIL-S-901 for Grade A, Class 1 equipment.

S5.1.1 Mechanical Shock Test—This test shall be conducted in accordance with MIL-S-901. All functions of the strainer assembly shall be unaffected by this test. Any unit not meeting MIL-S-901 shall be rejected.

S5.2 Vibration—The self-cleaning simplex strainers shall be designed and tested to function satisfactorily under the requirements of MIL-STD-167-1 Type 1 environmental vibration.

S5.2.1 Vibration Test—This test shall be conducted in accordance with MIL-STD-167-1. All functions of the strainer assembly shall be unaffected by this test. Any unit not meeting MIL-STD-167-1 shall be rejected.

S5.3 Acoustic Requirement—When operating, the strainer assembly shall conform to the airborne noise requirements of MIL-STD-740 for Grade C equipment.

S5.3.1 Acoustic Requirement Test—This test shall be conducted in accordance with MIL-STD-740. The sound energy limits imposed by MIL-STD-740 for Grade C equipment shall not be exceeded.

S5.4 Tests—Table S5.1 lists required tests; a test plan shall be submitted for approval before testing.

<table>
<thead>
<tr>
<th>Test</th>
<th>Requirement Paragraph(s)</th>
<th>Method Paragraph(s)</th>
</tr>
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<tbody>
<tr>
<td>Mechanical shock</td>
<td>S5.1</td>
<td>S5.1.1</td>
</tr>
<tr>
<td>Vibration</td>
<td>S5.2</td>
<td>S5.2.1</td>
</tr>
<tr>
<td>Acoustic requirement</td>
<td>S5.3</td>
<td>S5.3.1</td>
</tr>
</tbody>
</table>

S6. Other Requirements

S6.1 Subcontracted Material and Parts—The packaging requirements of referenced documents listed in Section S1 do not apply when material and parts are acquired by the contractor for incorporation into the equipment and lose their separate identity when the equipment is shipped.

S6.2 Repair Parts—A repair parts kit shall be furnished and delivered with each assembly. The kit shall contain the parts and quantities specified in the contract.

S6.3 Depreservation Instructions—A set of instructions covering the depreservation of the equipment shall be furnished. Instructions shall show all information necessary for depreservation, such as, but not limited to: the addition of lubricants prior to operation, flushing of lines, removal of greaseproof barrier and the location of detached components. Instructions shall be packaged in a transparent waterproof plastic bag, minimum 4 mil (100 µm) thick. Closure shall be by heat sealing. The shipping container in which the instructions are packed shall be marked to so indicate.
Standard Practice for Preparing Shipboard Fire Control Plans

INTRODUCTION

Title 46 of the Code of Federal Regulations 35.10-3, 78.45-1, and 97.36-1 contain the requirements for fire control plans aboard Coast Guard inspected vessels. When required, foreign and U.S. vessels on international voyages must comply with the 1974 International Convention for the Safety of Life at Sea (SOLAS). Contained in Regulation II-2/20 and 41-2 of the 1974 SOLAS Convention are requirements for shipboard fire control plans. This practice provides guidance on the symbols to be used in shipboard fire control plans, and has been developed in general conformance with the International Maritime Organization’s Assembly Resolution A.654(16).

1. Scope

1.1 This practice sets forth the symbols to be used in shipboard fire control plans.

2. Referenced Documents

2.1 ASTM Adjuncts:
   F 1626 Shipboard Fire Control Plan

3. Significance and Use

3.1 The fire control plan is a set of general arrangement plans for each deck of the ship that contains information that will be of use to the ship’s crew and shoreside firefighters in the event of a fire. Experience has shown that in casualties involving fire, one of the most valuable assets on the ship is the fire control plan. Most of the information the ship’s crew and shoreside fire fighting personnel would need, such as general layout and dimensions, fire fighting systems, and other systems that have a direct impact on fire fighting, are included in the fire control plan. The fire control plan is also ideal for firefighters and marine inspectors to use as a guide when taking tours on ships, since it contains the location of most items they will be looking for. In addition, having a consistent set of standard fire control plan symbols will eliminate the need for shoreside fire fighting personnel to know each ship’s respective fire control plan symbols.

4. General Requirements

4.1 The fire control plan symbols should be displayed on a general arrangement-type plan. The general arrangement-type plan should show all spaces on each deck, and the symbols used should identify the information needed for use by shipboard or shore-based firefighters. The information required to be displayed on fire control plans should be in accordance with the 1974 SOLAS Convention, Regulation II-2/20, 41-2 or as determined by the vessel’s flag administration, or both.

5. Physical Requirements

5.1 Dimension—Shall be as required by scale.

5.2 Scale—The scale used on fire control plans shall allow for clear and legible representation of all symbols and lettering.

5.3 Color—Finish shall allow for good contrast and representation of the color symbols.

6. Symbols

6.1 A legend identifying all symbols and supplementary symbols or figures shall be provided.

6.2 Scale of the symbol shall be the same size in relation to all others.

6.3 The effectiveness of these symbols may be enhanced by the use of supplementary indicators. If such indicators are used, they may be placed inside of, or adjacent to, the symbol as seen fit.

7. Illustration of Symbols

7.1 The symbols are available separately in an adjunct.

8. Keywords

8.1 fire control plans; fire fighting; marine technology; shipboard fire; ships
Standard Specification for
Insulation Monitors for Shipboard Electrical Systems
[Metric]¹

1. Scope

1.1 This specification covers two (2) types of electrical system insulation monitoring devices.

1.1.1 Type I is an ac device intended as a permanently installed unit for use in the detection of ohmic insulation faults to ground in active ac ungrounded electrical systems up to 1000 VAC, having dc components up to 1500 VDC.

1.1.2 Type II is a dc device intended as a permanently installed unit for use in the detection of ohmic insulation faults to ground in dc ungrounded electrical systems up to 1500 VDC.

1.2 Limitations—This specification does not cover devices that are intended for operation in ac ungrounded systems without dc components.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 7 of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 UL Standard:
UL STD 840 Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment²

2.2 IEC Standards:
IEC 255-5 Insulation Tests for Electrical Relays³
IEC 364-4-41 Electrical Installations of Buildings/

Protection for Safety/Protection Against Electrical Shock³

2.3 Military Standard:
MIL-STD-1399 (NAVY) Section 300A Interface Standards for Shipboard Systems; Electrical Power, Alternating Current⁴

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 ac or dc ungrounded electrical system, n—a system that has no intentional connection to ground and can continue to perform normally if one conductor becomes connected to ground.

3.1.2 measuring signal, n—the output signal from the insulation monitor that is superimposed between the ac or dc ungrounded system to be monitored and ground.

3.1.3 response value, n—the adjustable or preset set-point value of the system insulation resistance at which an insulation monitor will provide an alarm indication.

3.1.4 system leakage capacitance, n—the total capacitance to ground of the system including all connected consumers.

3.1.5 touch voltage, n—the voltage appearing during an insulation fault, between simultaneously accessible parts. This term is used only in connection with protection against indirect human contacts, that is, no direct human contact with a live conductor. The International Electrotechnical Commission (IEC) limits the maximum prospective touch voltage which can be maintained indefinitely to 50 VAC rms or 120 V ripple-free dc.

4. Ordering Information

4.1 Orders for monitoring devices under this specification shall state the following information:

4.1.1 Type and quantity.

4.1.2 Nominal system voltage and frequency (for ac system).

4.1.3 Input supply voltage.

4.1.4 Response value/set-point range expressed in K-Ohms.

¹ This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 in Electrical.
² Available from Underwriters Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.
³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
⁴ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.
4.1.5 ASTM designation and year of issue.
4.1.6 System leakage capacitance or data from which an estimate of its magnitude can be determined.
4.1.7 Special requirements such as Test/Reset buttons, ohmmeters, visual indicators, memory fault retention, and so forth.

5. Materials and Manufacturing Methods
5.1 The materials and manufacturing methods used shall be such that the resulting products will conform to the properties and characteristics prescribed in this specification.

6. Performance Requirements
6.1 Response of Insulation Monitor to a Step Input—The insulation monitor measures the combined parallel resistance to ground from all power or circuit conductors. The time to respond to a step change in the actual resistance to a value less than or equal to 50% of the desired response value shall be governed by the expression:

\[ t(s) \leq 100 + 40(R_i \times C_s) \]  

where
\[ R_i = \text{internal resistance of monitor, ohm, and} \]
\[ C_s = \text{total system capacitance, farad.} \]

For example,
\[ t = 124 \text{ s if } R_i = 120,000 \text{ ohm and } C_s = 5 \times 10^{-6} \text{ farad.} \]

6.2 Measuring Signal Voltage Limits—The peak value of the measuring signal shall be limited to a magnitude deemed acceptable by applicable safety standards for the intended use. The peak value of the measuring signal shall be less than the touch voltage limits: 120 VDC ripple-free and 50 VAC rms.

6.3 Internal Impedance and Internal Resistance—The internal impedance and dc internal resistance shall be at least 30 ohms per volt nominal system voltage but in either case shall not be less than 12 K-Ohms.

6.4 Response Tolerance—The response tolerance of the monitor shall not exceed 0 to +50% of the upper value of the set point range when measured at a room temperature of 25 ± 5°C (72 ± 9°F), with an input supply voltage 80–115% of its nominal value and with a system leakage capacitance equal to the value at which the monitor is calibrated (1 µfd minimum).

6.5 Working Range of System Voltage and Frequency—The insulation monitor shall perform as specified when operating with a system voltage of 0–115% nominal over the frequency range 50–400 Hz.

6.6 Self-Test—The insulation monitor shall include a built-in test device or be equipped with connection provisions for a separate device that shall be furnished with the equipment which can verify the proper functioning for the monitor.

6.7 Output Relay—The insulation monitor shall have provisions for an external (remote) audible or visual alarm to operate when the insulation resistance value falls below the set-point value or a remote indication of the insulation resistance value of the ungrounded system, or both. Built-in relays contacts for connection to an external alarm shall have a continuous rating of at least 4 amperes at 250 VAC. The break capacity shall be at least 2 amps at 250 VAC (0.7 power factor) and 0.3 amps at 120 VDC.

6.8 Built-In Display of Insulation Resistance—If provisions are made to indicate (display) the current insulation resistance level, then the manufacturer shall provide information as to the accuracy of this indication during normal operating conditions.

6.9 Clearance and Creepage Distances—The insulation monitor shall have protective spacings through air (clearance) and over surface (creepage) as stated in UL STD 840 for the intended maximum circuit voltage.

6.10 Impulse Voltage Withstand Tests—The insulation monitor shall meet the IEC 255-5 Class III Impulse Voltage Withstand Test Requirements.

7. Operating Environment
7.1 The insulation monitor shall reliably function over an ambient temperature range of 0 to 50°C (32 to 122°F) and at a relative humidity of 95%. Storage temperatures of −20 to +60°C (−4 to 140°F) shall not damage the insulation monitor.

8. Test Methods
8.1 Conformance Test—Conformance testing of insulation monitors shall be performed to confirm that the response tolerances stipulated are not exceeded and that the requirements of Section 6 are met.

8.1.1.1 An insulation monitor with adjustable response shall be tested at the beginning, mid and end points of its range. These tests shall be done without connected capacitances. The test resistor must be decreased slowly to ensure that a static response value is read. If the measuring principle is dependent on the system leakage capacitance, the tolerances must be tested in accordance with 6.4. This test is done by increasing the test capacitance step by step to the value at which the monitor was calibrated.

8.1.2 Testing of Response Time—At a system leakage of 1 µfd, there shall be a step change in the insulation level from nearly infinity to 50% of the derived response value. The time for the output relay to react shall be measured.

8.1.3 Testing of Peak Voltage—Peak voltage measurements are taken to confirm that the requirements for 6.2 are met. The voltmeter’s internal resistance should have a minimum value not less than 20 times the dc internal resistance of the measuring circuit.

8.1.4.1 Testing the ac Internal Impedance—The ac internal impedance specified in 6.3 is verified without any input supply voltage, with an rms milliammeter and with an external power supply wired between the linked measuring terminals and the...
ground terminal. The power supply must have an ac output rated at nominal voltage, nominal frequency, a harmonic distortion of less than 5% and internal impedance of under 10 ohms. The monitor’s internal impedance is calculated as follows:

\[ Z_r = \frac{\text{Nominal System Voltage}}{\text{ac rms Current}} \]  \hspace{1cm} (2)

8.1.4.2 Testing the dc Internal Resistance—The external power supply must have a dc output rated at nominal system voltage. The monitor’s internal resistance is calculated as follows:

\[ R_r = \frac{\text{Nominal System Voltage}}{\text{dc Current}} \]  \hspace{1cm} (3)

8.1.5 Testing of Built-in Meters—If indication instruments are built into the insulation monitor, they must be checked so that they comply with the response tolerances laid down in 6.8.

8.1.6 Testing the Impulse Voltage Withstand Capabilities—These tests will follow the procedure outlined in IEC 255-5 Class III.

8.2 Routine Tests—Each monitor must undergo a test during production to prove that the insulation monitor functions correctly.

8.2.1 Testing of Response Value—Routine tests should be performed at room temperature 25 ± 5°C (72 ± 9°F) with rated input supply voltage. The insulation monitor must comply with the requirements of 6.4.

8.2.1.1 The response of the insulation monitor is to be tested at the beginning and end points of the range if it has a steplessly adjustable response value.

8.2.2 Testing of Self-Test Function—The internal and external test buttons must be checked according to 6.6. The built-in test device’s proper functioning must be verified.

8.2.3 Testing of Built-in Meters—If the insulation monitor has built-in indication meters, they must be checked so that they comply with the response tolerances according to 6.8. The test should be performed at room temperature with rated input supply voltage.

8.2.4 Voltage Test—A voltage test is performed on the monitor to verify that the monitor is able to withstand an ac test voltage equal to twice the nominal systems voltage plus 1000 V for a period of one second without breakdown or flashover. The test voltages shall be applied directly to the terminals. Unless obvious, the independent circuits are those which are so described by the manufacturer.

8.2.4.1 Link all terminals of each independent circuit. Note that circuits having the same rated insulation voltage may be connected together when conducting the test in accordance with 8.2.4.3.c.

8.2.4.2 Link all terminals of open-contact² circuits.

8.2.4.3 Apply test potential: (a) between linked independent circuits; (b) between linked-independent circuits and linked open-contact circuits; (c) between linked independent circuits and exposed conductive parts.

8.2.5 Verification of Markings, Labels and Manuals—Visual examination should verify appropriate markings as specified in Section 9.


9.1 The following data shall be included on all enclosures for insulation monitors:

9.1.1 Name of manufacturer.
9.1.2 Type of monitor.
9.1.3 Connection diagram.
9.1.4 Input supply voltage.
9.1.5 Nominal supply voltage and frequency (for ac systems).
9.1.6 Response value or response range.
9.1.7 Test resistance value.
9.1.8 Serial number or year of production.
9.2 Manufacturer’s equipment manual shall provide the following information in addition to the above requirement.
9.2.1 Description of operation.
9.2.2 ac internal impedance or dc internal resistance.
9.2.3 Connection diagram.
9.2.4 Nominal value of measuring signal.
9.2.5 Maximum measurement current.
9.2.6 Nominal contact voltage and current ratings for integral relays per 6.7.
9.2.7 A note advising that system leakage capacitance may influence the measurement.
9.2.8 A note advising that only one monitor may be connected per galvanic circuit and that one monitor must be disconnected when two ungrounded systems containing independent monitors are coupled together.

10. Keywords

10.1 ac electrical systems; dc components; dc electrical systems; electrical insulation monitoring; electrical systems; ohmic insulation faults
1. Scope

1.1 This specification covers the design, construction, testing and operating requirements for pressure-reducing manifolds for air or nitrogen systems, referred to herein also as manifolds. The term manifold constitutes the combination of all components and piping between, and including, the inlet and outlet ports (see Fig. 1 and Fig. 2).

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses (metric SI units) are for information only.

2. Referenced Documents

2.1 ASTM Standards:
F 992 Specification for Valve Label Plates
F 1508 Specification for Angle Style, Pressure Relief Valves for Steam, Gas, and Liquid Services
F 1795 Specification for Pressure-Reducing Valves for Air or Nitrogen Systems

2.2 American Society of Mechanical Engineers (ASME):
B1.1 Unified Screw Threads

2.3 Military Standards and Specifications:
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-740 Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment
MS 16142 Boss, Gasket Seal Straight Thread Tube Fitting, Standard Dimensions for
MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver-Brazing, General Specification for

3. Terminology

3.1 Definitions:
3.1.1 accuracy of regulation—the amount by which the downstream pressure may vary when the manifold is set at any pressure within the required set pressure range and is subjected to any combination of inlet pressure, flow demand, and ambient temperature variations within the specified limits.
3.1.2 bubble-tight—No visible leakage over a 5-min period using either water submersion or the application of bubble fluid for detection.
3.1.3 external leakage—Leakage from the manifold which escapes to atmosphere.
3.1.4 flow rate demand—the amount of flow demanded at any given time by the system downstream of the manifold.
3.1.5 flow rate demand range—the range over which the flow demand can vary.
3.1.6 hydrostatic shell test pressures—the hydrostatic test pressures that the inlet and outlet sections of the manifold are required to withstand without damage. Manifold operation is not required during application of shell test pressure, but the manifold must meet all performance requirements after the shell test pressure has been removed.
3.1.7 inlet operating pressure range—the range over which the inlet pressure supplied to the manifold can vary under any operational conditions which the manifold can be subjected to in service.
3.1.8 internal leakage—leakage from higher pressure to lower pressure portions of the manifold and which does not escape to atmosphere.
3.1.9 manifold rated pressures—the inlet and outlet pressure ratings of the manifold. These rated pressures are selected from the applicable pressure ratings (see 4.2) and specified in the ordering information (see Section 5). The inlet pressure rating is applicable from the manifold inlet up to and including the seats of the outlet stop valve and bypass throttle valve. The
outlet pressure rating is applicable from the outlet side of the seats of the outlet stop valve to the manifold outlet and the bypass throttle valve to the manifold outlet.

3.1.10 manual valves—these are all the manually operated valves in the manifold which include handwheel-operated valves and wrench-operated valves. The handwheel-operated valves are the inlet and outlet stop valves, and the bypass throttle valve. The wrench-operated valves are the upstream and downstream bleed valves and the gage isolation valve. The requirements for any manually operated valves installed in the pressure-reducing valve are covered under 6.5.1.

3.1.11 maximum flow rate demand—the maximum amount of flow demanded of the manifold by the downstream system.

3.1.12 maximum inlet operating pressure—the highest pressure supplied to the inlet of the manifold in service.

3.1.13 maximum outlet operating pressure—the highest pressure at the manifold outlet in service. This is established by the accuracy of regulation of the pressure-reducing valve.

3.1.14 maximum set pressure—the highest set pressure at which the manifold can meet the performance requirements specified.

3.1.15 minimum flow rate demand—the minimum flow rate demanded of the manifold by the downstream system.

3.1.16 minimum inlet operating pressure—the lowest pressure supplied to the inlet of the manifold in service.

3.1.17 minimum outlet operating pressure—the lowest pressure at the manifold outlet in service. This is established by the accuracy of regulation of the pressure-reducing valve.

3.1.18 minimum set pressure—the lowest set pressure at which the manifold can meet the performance requirements specified.

3.1.19 operating pressures—the pressures within the manifold during service.

3.1.20 pressure-reducing valve—the component of the manifold which accomplishes automatic regulation of the downstream pressure. In this component, the upstream pressure is reduced to the desired downstream pressure.

3.1.21 pressure-relief valve—the component of the manifold which protects the manifold and downstream systems against downstream over pressurization.

3.1.22 set pressure—the outlet pressure delivered by the manifold at the time the pressure setting is made. For the
purposes of this specification, it will be assumed that the setting is made when there is no flow demand on the manifold ("lock-up" condition), and the manifold is at surrounding ambient temperature.

3.1.23 set pressure range—the range of set pressures over which the manifold can be adjusted while meeting the performance requirements specified.

3.1.24 wide open capacity—the flow rate when a valve is in a position which presents the least resistance to flow.

4. Classification

4.1 Configuration—Manifolds shall be of the following configurations and specified in the ordering information (see 5.1).

   Configuration 1-1 One reducer, one relief (see Fig. 1).
   Configuration 2-1 Two reducers, one relief (see Fig. 2).

4.2 Pressure Ratings—Manifolds shall have inlet-rated pressures and outlet-rated pressures selected from the following categories: 400-, 1500-, 3000-, and 6000-psig (2.8-, 10.3-, 20.7-, and 41.4-MPa gage pressure). The inlet and outlet pressure ratings selected shall be specified in Section 5.

4.3 End Connections—Manifolds shall have inlet and outlet end connections selected from those listed in Table 1 and specified in Section 5.

5. Ordering Information

5.1 Ordering documentation for manifolds under this specification shall include the following information, as required, to describe the equipment adequately:

   5.1.1 ASTM designation and year of issue,
   5.1.2 Size and type of inlet end connection (see 4.3 and 6.4.2),
   5.1.3 Size and type of outlet end connection (see 4.3 and 6.4.2),
   5.1.4 Size and type of end connections for pressure-reducing valve and pressure-relief valve,
   5.1.5 If tail pieces and union nuts are required (when required, their material of construction shall be per Table 1),
   5.1.6 Manifold configuration, inlet and outlet pressure ratings (see 4.1 and 4.2),
   5.1.7 Manifold inlet operating pressure range,
   5.1.8 Type of mounting required: bottom or back mounting (see 6.4.3),
   5.1.9 Set pressure and set pressure range, if other than specified (see 7.3),
   5.1.10 Flow rate demand range (see 7.1, S1.1.6),
   5.1.11 Accuracy of regulation required, if other than specified, or if set pressure is below 10 psig (see 7.2),
   5.1.12 Relief valve set pressure and accumulation pressure (if different from Specification F 1508),
   5.1.13 Ambient atmospheric conditions: temperature range, chemical contaminants, if any,
   5.1.14 Quality of inlet air/nitrogen gas: temperature range, moisture content, oil/lubricant contaminants, if any,
   5.1.15 Special tools required (see 6.7),
   5.1.16 Tamper-proof lead seal if required (see Specification F 1795, Section 5),
   5.1.17 Supplementary requirements, if any (S1 through S4), and
   5.1.18 Maximum vibration frequency, if other than specified (see S1.1.9).

6. Manifold Construction

6.1 Manifolds shall incorporate the design features specified in 6.2-6.11.

6.2 Materials of Construction—Material requirements for the assemblies in the manifold shall be as specified in the applicable component specifications referenced herein. Materials for all other parts, including the inlet and outlet manifold blocks, shall be 300 series corrosion-resistant steel (SS304, 304L, 316, or 316L) or other materials selected to provide weldability and corrosion resistance without requiring painting, coating, or plating. The inlet and outlet manifold blocks shall be weld repairable. Materials for contacting parts shall be selected to minimize electrolytic corrosion and galling. Metallic materials shall conform to applicable ASTM specifications. Nonmetallic materials shall be compatible with the line medium.

6.3 General Requirements—Manifolds shall incorporate the functional elements shown schematically in Fig. 1 or Fig. 2, as applicable, and delineated below:

   (a) Inlet and outlet stop valves,
   (b) Upstream and downstream bleed valves (for depressurization of all components and fluid cavities),
   (c) Pressure-reducing valve(s),
   (d) Pressure-relief valve,
   (e) Gauge isolation valve, and
   (f) Bypass throttle valve.

All components shall be part of a manifold assembly, as shown in Fig. 3 or Fig. 4, as applicable, which requires only one inlet and one outlet connection to the main flow path of the piping system in which it is installed. The inlet and outlet connections shall be in-line. The manifold shall be fabricated from inlet and outlet blocks, with interconnecting piping for the pressure-reducing valve(s) and bypass throttle valve flow paths. The manual valves shall be cartridge mounted into the inlet and outlet manifold blocks as shown in Fig. 3 or Fig. 4, as applicable. The pressure-reducing valve and the pressure-relief valve shall be mounted by way of takedown connections in accordance with Table 1. The manifold shall be capable of meeting all requirements of this specification and provide extended reliable operation when protected by a 5-µm nominal/
18-µm absolute filter installed upstream of the manifold inlet and when subjected to conditions specified in Section 5.

6.4 Design Construction Requirements

6.4.1 Pressure Envelope—The hydrostatic shell test pressures shall be 1.5 times the manifold rated inlet and outlet pressures.

6.4.2 Connections—The main-line inlet and outlet connections of the manifold, the inlet and outlet connections of the pressure-reducing valve(s), the connections for the bypass line, and the inlet and outlet connection to the pressure-relief valve shall be takedown joints (unions or other as specified) as specified in Table 1 based on rated pressures specified. Any exposed threads shall be protected by plastic caps for shipping. The main-line inlet and outlet connection of the manifold and the inlet and outlet connection for the pressure-reducing valve(s) shall permit axial adjustment to expedite proper installation of the manifold into the piping system and to facilitate replacement of the pressure-reducing valve(s) with one of another make or model or which is for some other reason not dimensionally identical to the originally installed pressure-reducing valve(s). The axial adjustment feature for the pressure-reducing valve(s) shall be included in that portion of the takedown joints that are connected to the inlet and outlet manifold blocks. If unions per Table 1 are specified for the pressure-reducing valve(s) inlet and outlet connections, the thread pieces shall be the portions of the unions that are attached to the pressure-reducing valve(s). The range over which each of the four adjustable connections noted above can be adjusted shall be as specified in Table 2. A positive and permanent means shall be incorporated to ensure that none of the four adjustable connections can be backed out beyond their minimum engagement position. The size of the main-line inlet and outlet connections of the manifold shall be as specified (see Section 5).

6.4.3 Manifold Mounting—The manifold shall be given structural integrity by means of a subplate provided as part of the manifold. The subplate shall be an angle form to provide an accurate mounting surface for both back and bottom mounting and shall be bolted to the inlet and outlet manifold blocks in such a way as to not interfere with mounting the manifold to a foundation plate. The manifold shall be drilled and tapped or through-drilled to allow either bottom mounting or back mounting as specified (see Section 5). All components shall be fully and easily accessible for operation, service, or removal from the manifold.

6.4.4 Threads—Threads shall be as specified in ASME B1.1. Where necessary, provisions shall be incorporated to prevent the accidental loosening of threaded parts. The design shall be such that standard wrenches can be used on all external bolting. Lock wire shall not be used.

6.4.5 Interchangeability—The entire manifold, including components and all associated piece parts, shall have part number identity and shall be replaceable from stock or the manufacturer on a nonselective and random basis. Parts having the same manufacturer’s part number shall be directly interchangeable with each other with respect to installation (physical) and performance (function). Physically interchangeable assemblies, components, and parts are those that are capable of being readily installed, removed, or replaced without alteration, misalignment, or damage to parts being installed or to adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.4.6 Nonmetallic Element Interchangeability—Nonmetallic elements, including but not limited to, seat rings, poppet seat inserts, cushions, and O-rings, shall be treated as separately identified and readily replaceable parts.
6.4.7 Pressure Gage—The manifold shall be provided with a ¼-in. (DN 8) threaded gage connection port to permit attachment of a pressure gage for sensing the outlet pressure. The gage connection under all operating conditions shall be located to measure accurately pressure at the manifold outlet connection when using either the pressure-reducing valve or the bypass throttle valve to control flow. A gage isolation valve shall be provided in the manifold.

6.4.8 Bleed Valves—Bleed valves as shown in Fig. 1 and Fig. 2 shall be provided to allow depressurization of piping and components.

6.5 Component Requirements:

6.5.1 Pressure-Reducing Valve—Pressure-reducing valve(s) incorporated in the manifold shall be in accordance with Specification F 1795, Type I construction. The pressure rating shall be in accordance with 4.2 and shall equal the manifold inlet pressure rating.

6.5.1.1 Pressure reversal—The manifold shall withstand, without damage, a condition in which the pressure-reducing valve is subjected to a maximum reverse pressure differential. This can occur where the maximum set pressure exists at the pressure-reducing valve outlet, the pressure-reducing valve loading element is deactivated (that is, if it is a spring-loaded, pressure-reducing valve, the set spring adjustment is backed off fully; and if a gas-dome loaded pressure-reducing valve, the dome charge is vented off completely), and inlet pressure is vented off.

6.5.2 Pressure-Relief Valve—The requirements and definitions for the pressure-relief valve incorporated in the manifold shall be as specified in Specification F 1508.

6.5.3 Manual Valves—The requirements for the manual valves incorporated in the manifold shall be as specified in 6.5.3.1-6.5.3.6.

6.5.3.1 Mounting—All manual valves shall be cartridge mounted into the manifold blocks.

6.5.3.2 Seats—Each manual valve shall incorporate a non-metallic seating feature for tight shutoff.

6.5.3.3 Handwheel operating force—For hand-operated valves, the maximum permissible total tangential force required on the rim of the handwheel for operating, or seating/unseating the valves shall not exceed 50 lbs (220 N) when the valve is subjected to the maximum operating pressure.

---

<table>
<thead>
<tr>
<th>TABLE 2 Adjustable Range of End Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection Size</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>¼ and ⅜ (8 and 10)</td>
</tr>
<tr>
<td>½, ⅜, ⅓, ⅔ (15, 20, 25, and 32)</td>
</tr>
<tr>
<td>1⅛ and 2 (40 and 50)</td>
</tr>
</tbody>
</table>

---

FIG. 4 Components of Manifold Assembly
6.5.3.4 Bidirectional shutoff—All manual valves shall be capable of operation and tight shutoff when pressure is applied in either direction.

6.5.3.5 Pressurization rate—All manual valves shall be capable of being operated to limit the rate of downstream pressure buildup in a depressurized volume (with maximum pressure upstream) to 200-psig (1379-KPa gage pressure) per second. Downstream volumes for this pressurization rate requirement shall be taken as the applicable manifold volumes. For design and test purposes, a stop valve not more than ten diameters downstream of the manifold outlet connection shall be assumed.

6.5.3.6 Bypass throttle valve—The bypass throttle valve shall be sized to pass full-rated flow of the manifold and control the outlet pressure at all flow demands and inlet pressures within the range of the manifold.

6.6 Manifold Envelope Dimensions—Manifold envelope dimensions shall be as specified in Fig. 3 or Fig. 4 and Table 3, as applicable.

6.7 Maintainability—The manifold shall permit direct access for disassembly, repair, and reassembly of all internal working parts and subassemblies when mounted for operation on its subplate and installed into the system. Maintenance shall require standard tools to the maximum extent possible. Any special tools required for maintenance shall be identified and shall be supplied when ordered (see Section 5).

6.8 Reversibility—Seating inserts shall not be physically reversible unless they are also functionally reversible to preclude incorrect assembly.

6.9 Adjustments—There shall be no adjustments required in the manifold during or after assembly other than the axial positioning of the takedown connections for installation of the pressure-reducing valve into the manifold or installation of the manifold into the system and the set points of the pressure-reducing valve and the pressure-relief valve.

6.10 Reliability—Periodic maintenance of the manifold or any of its components shall not be required. There shall be no postassembly lubrication required.

6.11 Ruggedness—To the maximum extent practical, the manifold and its components shall be designed to prevent damage, malfunction, or leakage as a result of foreign particle or other line media contamination or from mishandling.

7. Performance

7.1 Manifolds shall meet the performance requirements of 7.2-7.7.

7.2 Flow Capacity—The maximum and minimum flow rate demand required shall be specified (see Section 5) in standard cubic feet per minute at 60°F (15.6°C) and 14.7 psia (101 kPa absolute). The manifold shall meet the specified maximum and minimum flow rate demand requirements, or any intermediate flow rate demand requirement, and shall operate without hunting or chattering under all specified conditions.

7.3 Accuracy of Regulation—Manifold regulated pressure shall be maintained within the accuracy of regulation limits specified in Table 4 (unless different limits are specified in Section 5) under all flow rate demand and inlet pressure conditions specified.

7.4 Range of Set Pressure Adjustment (Set Pressure Limits)—Unless otherwise specified in Section 5, the set pressure range shall be as follows: Where the manifold uses a mechanical spring, the set pressure shall be adjustable through a range of at least 5% or 2 psi (14 kPa), whichever is greater, on either side of the specified set pressure. Where the manifold uses a gas spring (dome loading), the set point shall be adjustable through a range of at least 25% or 10 psi (69 kPa), whichever is greater, on either side of the specified set pressure.

7.5 Accumulation—The pressure-relief valve shall be sized to pass at the maximum inlet pressure the wide open capacity of the pressure-reducing valve, or the wide open capacity of the by-pass throttle valve, whichever is greater, and limit the downstream pressure to the accumulation pressure. The accumulation (overpressure) limits shall be per Specification F 1508.

### Table 3: Envelope Dimensions of Manifolds

<table>
<thead>
<tr>
<th>Manifold Size (Inlet x Outlet), in. (DN Metric)</th>
<th>Distance Between Takedown Joints (At Adj. Mid-Point)</th>
<th>C ±0.12 in. Configuration 1–1 (3 mm)</th>
<th>C ±0.12 in. Configuration 2–1 (3 mm)</th>
<th>D (Max) in. (mm)</th>
<th>E ±0.06 in. (±2 mm)</th>
<th>F (Min) (mm)</th>
<th>G ±0.06 (±2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 x 1/4 (DN 8 x 8)</td>
<td>19 (483)</td>
<td>6 1/2 (159)</td>
<td>6 1/2 (165)</td>
<td>9 1/2 (241)</td>
<td>12 (305)</td>
<td>4 (102)</td>
<td>3 1/8 (89)</td>
</tr>
<tr>
<td>1/4 x 1/4 (DN 8 x 15)</td>
<td>19 1/2 (495)</td>
<td>6 1/2 (165)</td>
<td>6 1/2 (165)</td>
<td>10 1/4 (260)</td>
<td>12 1/4 (311)</td>
<td>4 1/4 (108)</td>
<td>3 3/8 (95)</td>
</tr>
<tr>
<td>1/4 x 1/4 (DN 8 x 20)</td>
<td>20 (508)</td>
<td>6 1/2 (171)</td>
<td>6 1/2 (171)</td>
<td>10 1/4 (260)</td>
<td>12 1/2 (318)</td>
<td>4 1/2 (114)</td>
<td>4 (102)</td>
</tr>
<tr>
<td>1/4 x 1/4 (DN 10 x 10)</td>
<td>21 (533)</td>
<td>6 1/2 (178)</td>
<td>6 1/2 (178)</td>
<td>11 1/2 (292)</td>
<td>13 (330)</td>
<td>4 1/2 (114)</td>
<td>4 1/2 (114)</td>
</tr>
<tr>
<td>1/4 x 1/4 (DN 10 x 15)</td>
<td>21 1/2 (546)</td>
<td>6 1/2 (184)</td>
<td>6 1/2 (184)</td>
<td>12 1/4 (311)</td>
<td>13 1/4 (337)</td>
<td>5 (127)</td>
<td>4 1/2 (114)</td>
</tr>
<tr>
<td>1/4 x 1/4 (DN 10 x 20)</td>
<td>22 (559)</td>
<td>6 1/2 (191)</td>
<td>6 1/2 (191)</td>
<td>13 (330)</td>
<td>13 1/2 (343)</td>
<td>5 1/4 (133)</td>
<td>5 (127)</td>
</tr>
<tr>
<td>1/2 x 1/2 (DN 15 x 15)</td>
<td>23 (584)</td>
<td>8 (203)</td>
<td>8 (203)</td>
<td>14 (356)</td>
<td>14 (396)</td>
<td>5 1/4 (133)</td>
<td>5 1/4 (133)</td>
</tr>
<tr>
<td>1/2 x 1/2 (DN 15 x 20)</td>
<td>23 1/2 (597)</td>
<td>8 1/2 (210)</td>
<td>8 1/2 (210)</td>
<td>14 1/4 (375)</td>
<td>14 1/4 (368)</td>
<td>5 1/4 (133)</td>
<td>5 1/4 (133)</td>
</tr>
<tr>
<td>1/2 x 1/2 (DN 20 x 20)</td>
<td>24 (610)</td>
<td>8 3/4 (217)</td>
<td>8 3/4 (217)</td>
<td>15 (394)</td>
<td>14 3/4 (368)</td>
<td>6 (152)</td>
<td>5 1/2 (140)</td>
</tr>
<tr>
<td>3/4 x 3/4 (DN 20 x 20)</td>
<td>25 (635)</td>
<td>9 1/2 (229)</td>
<td>9 1/2 (229)</td>
<td>15 1/4 (394)</td>
<td>15 (381)</td>
<td>6 1/4 (159)</td>
<td>5 (146)</td>
</tr>
<tr>
<td>3/4 x 3/4 (DN 20 x 25)</td>
<td>25 1/2 (648)</td>
<td>9 1/2 (235)</td>
<td>9 1/2 (235)</td>
<td>16 1/4 (438)</td>
<td>15 1/2 (387)</td>
<td>6 1/4 (165)</td>
<td>5 1/2 (152)</td>
</tr>
<tr>
<td>3/4 x 3/4 (DN 20 x 30)</td>
<td>26 (660)</td>
<td>9 1/2 (241)</td>
<td>9 1/2 (241)</td>
<td>17 1/2 (457)</td>
<td>15 1/4 (394)</td>
<td>6 1/2 (165)</td>
<td>5 1/2 (152)</td>
</tr>
<tr>
<td>3/4 x 3/4 (DN 20 x 40)</td>
<td>26 3/4 (679)</td>
<td>9 1/2 (241)</td>
<td>9 1/2 (241)</td>
<td>18 (457)</td>
<td>15 1/4 (394)</td>
<td>6 1/2 (165)</td>
<td>5 1/2 (152)</td>
</tr>
<tr>
<td>1 x 1 (DN 25 x 25)</td>
<td>27 (686)</td>
<td>10 (254)</td>
<td>10 (254)</td>
<td>18 1/2 (470)</td>
<td>16 (406)</td>
<td>7 (178)</td>
<td>6 1/4 (152)</td>
</tr>
<tr>
<td>1 x 1 (DN 25 x 32)</td>
<td>27 1/2 (699)</td>
<td>10 1/2 (260)</td>
<td>10 1/2 (260)</td>
<td>19 1/2 (489)</td>
<td>16 1/4 (413)</td>
<td>7 1/11 (187)</td>
<td>6 1/2 (171)</td>
</tr>
<tr>
<td>1 x 1 (DN 25 x 40)</td>
<td>27 3/4 (706)</td>
<td>10 1/2 (260)</td>
<td>10 1/2 (260)</td>
<td>19 1/2 (489)</td>
<td>16 1/4 (413)</td>
<td>7 1/11 (187)</td>
<td>6 1/2 (171)</td>
</tr>
<tr>
<td>1 x 2 (DN 25 x 50)</td>
<td>28 (711)</td>
<td>10 1/2 (267)</td>
<td>10 1/2 (267)</td>
<td>19 1/2 (495)</td>
<td>16 1/4 (413)</td>
<td>7 1/11 (187)</td>
<td>6 1/2 (171)</td>
</tr>
</tbody>
</table>
7.6 **Seat Tightness**—Handwheel-operated valves shall be bubble-tight in both directions when closed with a force not exceeding that specified in 6.5.3.3 (or the manufacturers’ recommendations, when less). The pressure-reducing valve shall meet the seat tightness requirements of 8.5. Where necessary, leakage measurement shall start after temperature stabilization.

7.7 **External Leakage**—Manifold external leakage shall be bubble-tight at operating pressure conditions over a 5-min period.

8. **Tests Required**

8.1 Each manifold shall pass the tests outlined in 8.2-8.6.

8.2 **Visual Examination**—The manifold shall be examined visually to determine conformance with the ordering data, interface dimensions, and workmanship without disassembly.

8.3 **Hydrostatic Shell Test**—The manifold shall be hydro-statically tested by applying pressures equal to 1.5 times the manifold rated inlet and outlet pressures to the inlet and outlet ports, respectively, to check the structural integrity of the manifold. Pressure shall be applied for 5 min. Air or nitrogen may be used in lieu of water providing appropriate safety precautions are taken to minimize the risk associated with the use of a compressible fluid. There shall be no external leakage, permanent distortion, or structural failure.

8.4 **Relief-Valve Lift Test**—Pressure at the pressure-relief valve inlet shall be increased until the pressure-relief valve lifts. Pressure shall then be decreased until the pressure-relief valve resets. The pressure-relief valve shall lift and reseat within the limits specified in Specification F 1508. There shall be no evidence of operational instability or damage to the pressure-relief valve.

8.5 **Seat Tightness Test**—Handwheel-operated valves shall be seated with a torque not exceeding that specified in 6.5.3.3 (or the manufacturers’ recommendations, when less). Air, at the maximum inlet operating pressure each valve is subjected to in service, shall be used for seat leakage tests, using bubble fluid or immersing the outlet, or a line from the outlet, under water. The outlet stop valve shall also be tested in the outlet-to-inlet direction, applying pressure at the outlet of the valve equal to the maximum outlet-section rating of the manifold. Pressure-reducing valves shall be tested with an inlet pressure equal to the inlet rated pressure of the manifold. Pressure-relief valves shall be tested at the reseat pressure applicable to their setting in accordance with Specification F 1508. None of the valves shall show visible evidence of leakage over a 5-min period. The following procedure shall be used to check the pressure-reducing valve seat tightness: The valve shall be isolated downstream. The dead-ended volume shall be tight and shall not exceed ten diameters of downstream pipe. It shall be monitored with bubble fluid to assure tightness. With full-rated inlet pressure, there shall be no detectable rise in the outlet pressure over a 15-min period after manifold temperature stabilizes.

8.6 **External Leakage Test**—Air shall be applied at the appropriate rated pressure to each section of the manifold. External leakage shall be checked using bubble fluid or by submerging the manifold in water. There shall be no visible external leakage over a 5-min period.

9. **Marking**

9.1 **Identification Plate**—An identification plate of corrosion-resistant metal in accordance with Specification F 992; Types I, II, III, or IV shall be permanently attached to the manifold and shall include the following information (some or all information may instead be stamped or etched on the manifold blocks):

9.1.1 Manufacturer’s name,
9.1.2 ASTM designation and year of issue
9.1.3 Nominal operating conditions (inlet pressure, set pressure, and flow capacity), and
9.1.4 Manufacturer’s model/part number.

9.2 **Component Marking**—The pressure-reducing valve, pressure-relief valve, and each manual valve shall be marked or have an identification plate listing the manufacturer’s name and model/part number.

9.3 **Handwheel-Operated Valve Marking**—Each handwheel-operated valve shall be clearly marked to show its function in the manifold (for example, “Inlet Stop Valve,” “Outlet Stop Valve,” and “Bypass Throttle Valve”) and direction of operation of the handwheel movement to open or close the valve.

10. **Quality Assurance System**

10.1 The manufacturer shall establish and maintain a quality assurance system that will ensure all the requirements of this specification are satisfied. This system shall also ensure that all manifolds will perform in a similar manner to those representative manifolds subjected to original testing for determination of the operating and flow characteristics.

10.2 A written description of the quality assurance system the manufacturer will use shall be available for review and acceptance by the inspection authority.

10.3 The purchaser reserves the right to witness the production tests and inspect the manifolds in the manufacturer’s plant to the extent specified on the purchase order.

11. **Keywords**

11.1 air systems; nitrogen systems; pressure-reducing manifolds
S1. Initial Qualification Testing

S1.1 Qualification tests shall be conducted at a facility satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.1.1 through S1.1.11 and delineated in the ordering data. The tests may be conducted on representative manifold sizes and pressure classes to qualify all sizes and pressure classes of manifolds, provided the manifolds are of the same type and design. Evidence of prior approval of these tests is acceptable.

S1.1.1 Examination Before Testing—The manifold shall be examined visually to determine conformance with the ordering data, interface dimensions, and workmanship without disassembly.

S1.1.2 Relief-Valve Accumulation Test—The pressure-relief valve shall be tested for two conditions of accumulation capacity: (i) full-open pressure-reducing valve and (ii) full-open bypass valve. Maximum inlet operating pressure shall be maintained at the manifold inlet during this test. For the pressure-reducing valve portion, close the bypass valve, and block or otherwise modify the pressure-reducing valve to the wide-open fail condition. For the bypass valve portion, the pressure-reducing valve shall be isolated and the bypass valve fully opened. Under either condition, downstream pressure rise shall not exceed the accumulation pressure specified in Specification F 1508.

S1.1.3 Bypass Throttle Valve Functional Test—Minimum inlet operating pressure shall be maintained at manifold inlet. The pressure-reducing valve shall be isolated. The bypass throttle valve shall be opened until highest set pressure is maintained at maximum flow rate demand. Increase inlet pressure to maximum, then vary flow demand throughout the flow range of the manifold and verify ability of the bypass throttle valve to permit maintaining delivered pressure at the set point in a smooth, accurate manner.

S1.1.4 Bypass Throttle Valve Cycle Test—With maximum inlet pressure operating upstream, the bypass throttle valve shall be cyclic 100 times. There shall be no degradation to performance or evidence of damage or excessive wear. A cycle shall consist of a full opening and closing of the valve.

S1.1.5 Pressure Reversal Test—The manifold shall be tested to determine the susceptibility to damage when subjected to pressure reversal as specified in 6.5.1.1. It shall be set up with maximum inlet operating pressure and maximum set pressure. A separate means shall be included to insure that there is no loss of downstream pressure during this test. The reference load shall then be removed from the pressure-reducing valve set-point mechanism (if the pressure-reducing valve is spring loaded, all spring compression shall be backed off, if it is gas dome loaded, all dome charge shall be released). The inlet pressure shall then be released from the manifold, and this condition (no load on the pressure-reducing valve set point mechanism, zero pressure applied to the inlet side of the pressure-reducing valve seat, and maximum set pressure applied to the outlet side of the pressure-reducing valve seat) shall be maintained for a period of not less than 1 h. There shall be no leakage from the outlet to the inlet of the manifold. There shall be no evidence of damage to the pressure-reducing valve or any other portion of the manifold and no degradation to the performance capability of the manifold.

S1.1.6 Accuracy of Regulation Test—The manifold shall be tested for accuracy of regulation at each inlet pressure/set pressure combination defined below. At Condition D, flow shall be varied over the full range of flow rate demand as specified in Section 5. For Conditions A, B, and C, full-flow range testing is not required.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Inlet Pressure</th>
<th>Set Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>maximum</td>
<td>minimum</td>
</tr>
<tr>
<td>B</td>
<td>minimum</td>
<td>minimum</td>
</tr>
<tr>
<td>C</td>
<td>maximum</td>
<td>maximum</td>
</tr>
<tr>
<td>D</td>
<td>minimum</td>
<td>maximum</td>
</tr>
</tbody>
</table>

During each sequence (changing from Condition A to Condition B and changing from Condition C to Condition D), no alteration shall be made to the set pressure adjustment, or any other portion of the manifold, and the accuracy of regulation shall be maintained as required by Table 4. There shall be no instability or other evidence of unsatisfactory operation of the manifold during these tests. Flow in each condition shall be maintained long enough to demonstrate that the above requirements are met.

S1.1.7 Pressurization Rate Test—With the rated inlet pressure upstream, and a depressurized downstream volume as specified in 6.5.3.5, each handwheel-operated valve shall be operated to demonstrate its ability to meet the pressurization rate as specified in 6.5.3.5.

S1.1.8 Shock Test—The manifold shall be subjected to and meet the high-impact shock tests for Grade A, Class I as specified in MIL-S-901 pressurized with water, air, or nitrogen. The inlet port shall be pressurized to the maximum inlet operating pressure and the outlet port pressurized to the maximum outlet operating pressure. There shall be no structural damage to the manifold or any components. There shall be no degradation to the performance capability of the manifold. Momentary loss in pressure is permissible.

S1.1.9 Vibration Test—The manifold shall be vibration tested in accordance with Type I of MIL-STD-167-1 pressurized with air or nitrogen. The inlet port shall be pressurized to the maximum inlet operating pressure and the outlet port pressurized to the maximum outlet operating pressure. At frequencies up to and including 33 Hz (unless otherwise specified in the ordering information, Section 5), there shall be
no resonance in the range of frequency tested. There shall be no structural damage or degradation to the performance capability of the manifold.

S1.1.10 Noise Test—The manifolds shall be tested for airborne noise in accordance with MIL-STD-740-1. The noise (sound pressure level) shall not exceed 85 dBA observed at 1-m distance from the manifold.

S1.1.11 Posttest Examination—The manifold shall be disassembled and examined for any evidence of excessive wear, degradation, or impending damage or breakage.

S2. Technical Data and Certification Requirements

S2.1 Drawings—Assembly drawings of the entire manifold and each component which clearly depict design shall be provided. The following shall also be included as part of the drawings content:

S2.1.1 Bill of material listing specification, grade, condition, and any other data required to identify fully the properties of the materials proposed. This shall include identifications, material and size designations, shore hardness, and any other data necessary to identify the parts fully.

S2.1.2 In cases in which standard commercial or military parts are or can be used, these shall be appropriately identified.

S2.1.3 Outline dimensions, disassembly space, location, and size of end connections and mounts.

S2.1.4 Estimated weight and center of gravity (vertical, longitudinal, and transverse).

S2.1.5 Recommended assembly torques or equivalent procedures for making up all joints and threaded assemblies.

S2.1.6 The following information shall be included:

S2.1.6.1 Regulation:
(a) Set pressure and adjustable range.
(b) Specified operating conditions—range of inlet pressures and required range of capacity.
(c) Fail-open capacity (for purposes of pressure-relief valve sizing) of the pressure-reducing valve.
(d) Wide-open capacity (for purposes of pressure-relief valve sizing) of bypass throttle valve.

S2.1.6.2 Overpressure Protection for Pressure-Relief Valve:
(a) Set pressure and adjustable range.
(b) Rated capacity—accumulation.
(c) Reset pressure.

S2.2 Technical Manuals—The following shall be included as part of the manual contents:

S2.2.1 The assembly drawings for the manifold, supplemented by additional illustrations where necessary to illustrate operation and maintenance adequately. These additional illustrations may consist of blowouts or partial or full sections and may eliminate extraneous lines and details to clarify the interaction of parts.

S2.2.2 Table listing wrench sizes and assembly torques (or other equivalent procedures) for making up all joints and threaded assemblies.

S2.2.3 Detailed disassembly and reassembly procedures. In addition to a section providing procedures for the complete disassembly and reassembly of the manifold, maintenance and troubleshooting sections shall contain, or refer to, only the limited disassembly and reassembly required to accomplish each particular operation. This is intended to reduce the possibility of unnecessary disassembly and unnecessary disturbance of adjustments when performing specific or limited maintenance or troubleshooting operations.

S2.2.4 Adjustment procedures for the pressure-reducing and pressure-relief valve. For the pressure-relief valve, provide the approximate relationship between turns of the adjusting screw and set pressure change.

S2.3 Certification—Certification shall be provided indicating that the valve meets all requirements of the purchase order.

S3. Quality Assurance

S3.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.

S3.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.

S3.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

S3.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.

S3.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.

S3.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.

S3.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system that identifies status of material throughout all stages of manufacture.

S3.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions using documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.
S3.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.

S3.10 Welding—The quality control system shall include provisions for ensuring that welding conforms to specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made available to the inspection authority if required.

S3.11 Nondestructive Examination—Provisions shall be made to use nondestructive examination, as necessary, to ensure that material and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer or qualified by a recognized national body or both, and their authorizations/qualification records shall be made available to the inspection authority if required.

S3.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.

S3.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.

S3.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of material during all stages of manufacture and shall be able to distinguish between inspected and uninspected material.

S3.15 Calibration of Measurement and Test Equipment—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring, and test equipment to be used in verifying conformance to the specified requirements. Such calibration shall be traceable to a national standard and calibration records shall be maintained.

S3.16 Records Maintenance—The manufacturer shall have a system for the maintenance of inspection records, radiographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S3.17 Sample Forms—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S3.18 Inspection Authority—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with originals or copies of such documents.

S4. Special Material, Design, and Performance Considerations

S4.1 Recovered Materials—Unless otherwise specified herein, all equipment, material, and articles incorporated in the products covered by this specification shall be new and may be fabricated using materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term “recovered materials” means materials that have been collected or recovered from solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or rebuilt products is allowed under this specification unless otherwise specified.

S4.2 Pipe threads shall not be used in the manifold.

S4.3 Manifold performance shall not be adversely affected by the following line and ambient conditions:

S4.3.1 Ambient Atmospheric Conditions:
S4.3.1.1 Temperature: 40 to 120°F (4 to 49°C).
S4.3.1.2 Moisture content: Exposure to atmosphere containing salt-laden moisture.

S4.3.2 Quality of Inlet Air/Gas—Air or nitrogen moisture content between the limits of +20°F (−7°C) to −60°F (−50°C) dewpoint at 4500-psig (31.0-MPa gage pressure). Particulate contamination: Protected by 5-μm nominal/18-μm absolute filtration.

S4.4 Gage Connections—The ¼-in. (DN8) threaded gage connection (see 6.4.7) shall be in accordance with MS 16142.

This standard is issued under the fixed designation F 1716; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This guide covers a recommended plan for transition and acceptance of marine software that was developed by an activity other than the maintaining activity. It further provides a recommended iterative process model for managing and executing software maintenance activities.

2. Referenced Documents
2.1 ASTM Standards:
E 622 Guide for Developing Computerized Systems
E 919 Specification for Software Documentation for a Computerized System
E 1013 Terminology Relating to Computerized Systems

2.2 IEEE Standards:
100 Standard Dictionary for Electrical and Electronic Terms
610 Standard Glossary of Software Engineering Terminology
1063 Standard for Software User Documentation
1074 Standard for Developing Software Life Cycle Processes
1219 Standard for Software Maintenance

2.3 ANSI Standards:

2.4 Military Standards and Specifications:
MIL-STD 498 Software Development and Documentation

3. Terminology
3.1 The terminology used in this guide is defined in Terminology E 1013 and Guide E 622.
3.2 Other computer-related terms in this guide are defined in IEEE 100 and IEEE 610.12.

4. Significance and Use
4.1 This guide provides a recommended transition plan for a marine software maintainer, when the maintainer is other than the supplier, to develop the capability to make extensive changes or extensions to the programs. Further, this guide provides a recommended interactive process model for managing and executing software maintenance activities. This guide applies principally to the marine software that requires design effort and for which the product requirements are stated principally in performance terms.

5. Software Transition Plan
5.1 The software transition plan is developed when the software support concept calls for transition of responsibility from the developer to a separate support agent. The software transition plan identifies hardware, software, and other resources needed for life cycle support of deliverable software and describes the developer’s plans for transitioning deliverable items to the support agent. The developer shall identify all software development resources needed by the support agent to fulfill the support concept specified in the contract. The developer shall develop and record plans identifying these resources and describing the approach to be followed for transitioning deliverable items to the support agent. The planning shall include the following.

5.1.1 Software Support Resources—Description of the resources needed to support the deliverable software. These resources shall include items needed to control, copy, and distribute the software and its documentation, and to specify, design, implement, document, test, evaluate, control, and distribute modifications to the software. This includes needed
compilers, linkers, locators, mappers, and tools such as configuration utilities. In addition, include as applicable, any special operating systems.

5.1.2 Facilities—Description of the facilities needed to support the deliverable software. These facilities may include special rooms, mock-ups, special power requirements, and so forth.

5.1.3 Hardware—Identification and description of the hardware and associated documentation needed to support the deliverable software. This hardware may include computers, peripheral equipment, hardware simulators, stimulators, emulators, diagnostic equipment, and non-computer equipment. The description shall include:

5.1.3.1 Specific models, versions, and configurations.
5.1.3.2 Rationale for the selected hardware.
5.1.3.3 Reference to user/operator manuals or instructions for each item, as applicable.
5.1.3.4 Identification of each hardware item and document as acquirer-furnished, any item that will be delivered to the support agent, any item the support agent is known to have, any item that will be delivered to the support agent shall address the following:

5.1.3.5 When items must be acquired, information about a current source of supply, including whether the item is currently available and whether it is expected to be available at the time of delivery.
5.1.3.6 Information about manufacturer support, licensing, and data rights, including whether the item is currently supported by the manufacturer, whether it is expected to be supported at the time of delivery, whether licenses will be assigned to the support agent, and the terms of such licenses.
5.1.3.7 Privacy considerations or limitations.
5.1.4 Software—Identification and description of the software and associated documentation needed to support the deliverable software. This software may include computer-aided software engineering (CASE) tools, data in these tools, compilers, test tools, test data, simulations, emulations, utilities, configuration management tools, databases and data files and other software. The description shall include:

5.1.4.1 Specific names, identification numbers, version numbers, release numbers, and configurations, as applicable.
5.1.4.2 Rationale for the selected software.
5.1.4.3 Reference to user/operator manuals or instructions for each item, as applicable.
5.1.4.4 Identification of each software item and document as acquirer-furnished, any item that will be delivered to the support agent, any item the support agent is known to have, any item the support agent must acquire, or other description of status.
5.1.4.5 When items must be acquired, information about a current source of supply, including whether the item is currently available and whether it is expected to be available at the time of delivery.
5.1.4.6 Information about vendor support, licensing, and data rights, including whether the item is currently supported by the vendor, whether it is expected to be supported at the time of delivery, whether licenses will be assigned to the support agent, and the term of such licenses.

5.1.4.7 Privacy considerations and limitations.
5.1.4.8 Certification of virus protection measures taken including identification and version of software used.
5.1.5 Other Documentation—Identification of any other documentation needed to support the deliverable software. This list will include, for example, plans, reports, studies, specifications, design descriptions, test cases/procedures, test reports, user/operator manuals, and support manuals for the deliverable software, including the following:

5.1.5.1 Names, identification numbers, version numbers, and release numbers, as applicable.
5.1.5.2 Rationale for including each document.
5.1.5.3 Identification of each document as acquirer-furnished, any item that will be delivered to the support agent, any item the support agent is known to have, any item the support agent must acquire, or other description of status.
5.1.5.4 When a document must be acquired, information about where to acquire it.
5.1.5.5 Information about licensing and data rights.
5.1.5.6 Privacy and limitations.
5.1.5.7 Beta Testing and Verification and Validation Records—Records of Beta Testing and Verification and Validation shall be provided if applicable.
5.1.5.8 Description of significant problems and changes made during the development process.
5.1.6 Personnel—Description of the personnel needed to support the deliverable software, including anticipated number of personnel, and types and levels of skills and expertise.
5.1.7 Other Resources—Identify any other resources needed to support the deliverable software, including consumables.
5.1.8 Interrelationship of Components—Identify interrelationships of the components identified above. Figures may be used to show interrelationships.
5.1.9 Recommended Procedures—Describe any procedures, including advice and lessons learned, that the developer may wish to recommend to the support agent for supporting the deliverable software and associated support environment.
5.1.10 Training—Describe the developer’s plans for training support personnel to support the deliverable software.
5.1.11 Anticipated Areas of Change—Describe anticipated areas of change to the deliverable software.
5.1.12 Transition Planning—Planning shall be performed for all activities to transition the deliverable software to the support agent. Plans for transitioning the deliverable software to the support agent shall address the following:

5.1.12.1 The activities to be performed to transition the deliverable software to the support activity. These activities may include planning/coordination meetings; preparation of items to be delivered to the support agent; packing, shipment, installation, and checkout of the software support environment; packing, shipment, installation and checkout of the operational software; and training of the support personnel.
5.1.12.2 Designation of the roles and responsibilities for each activity.
5.1.12.3 The resources needed to carry out the transition activities and which party will perform each activity.
5.1.12.4 Schedules and milestones for conducting the transition activities.
5.1.12.5 Procedures for installation and checkout of the deliverable items of the support environment.

6. Software Maintenance
6.1 System software maintenance commences after the transition and acceptance of the developed software by the software support activity. Software maintenance can be identified by either user/customer or system maintainer. The processes of IEEE 1219 are recommended as a model for software maintenance.

7. Support Agent Software Process Maturity
7.1 The processes of the software support agent are recommended to be certified to at least Level Two as defined in the Software Engineering Institute (SEI) Capability Maturity Model for Software Version 1.1,6 equivalent to ANSI/ISO/ASQC Q 9000-3.

8. Keywords
8.1 computerized systems; marine technology; ships; software; software maintenance; software support

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6 Available from Research Access, Inc. (RAI), 800 Vinial Street, Pittsburgh, PA 15212.
Standard Specification for
Rotary Positive Displacement Distillate Fuel Pumps

This standard is issued under the fixed designation F 1718; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the requirements applicable to the design and construction of rotary positive displacement distillate fuel pumps for shipboard use.

1.2 Lineal dimensions and units of force in this specification are expressed as inches and pounds respectively. A companion metric standard is in the process of preparation.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A 36M Specification for Carbon Structural Steel
A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
A 276 Specification for Stainless Steel Bars and Shapes
A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 434 Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered
A 449 Specification for Quenched and Tempered Steel Bolts and Studs
A 563 Specification for Carbon and Alloy Steel Nuts
A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
A 574 Specification for Alloy Steel Socket-Head Cap Screws
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening
B 148 Specification for Aluminum-Bronze Sand Castings
B 150 Specification for Aluminum Bronze Rod, Bar, and Shapes
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
B 221 Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
B 271 Specification for Copper-Base Alloy Centrifugal Castings
B 505 Specification for Copper-Base Alloy Continuous Castings
B 584 Specification for Copper Alloy Sand Castings for General Applications
D 1418 Practice for Rubber and Rubber Lattices—Nomenclature
D 2000 Classification System for Rubber Products in Automotive Applications
D 3951 Practice for Commercial Packaging
F 104 Classification System for Nonmetallic Gasket Materials
F 467 Specification for Nonferrous Nuts for General Use
F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
F 594 Specification for Stainless Steel Nuts
3. Terminology

3.1 Definitions:

3.1.1 capacity, \( n \)—the quantity of fluid actually delivered per unit of time at the rated speed, including both the liquid and dissolved or entrained gases, under stated operating conditions.

3.1.2 Discussion—In the absence of any gas or vapor entering or forming within the pump, the capacity is equal to the volume displaced per unit of time, less slip.

3.1.3 capacity, maximum, \( n \)—the quantity of fluid delivered that does not exceed the limit determined by the formula in 4.1.2.1.

3.1.4 capacity, rated, \( n \)—the minimum quantity of fluid delivered at the specified conditions of discharge pressure, inlet pressure and viscosity as shown in Table 1.

3.1.5 displacement, \( n \)—the volume displaced per revolution of the rotor(s).

3.1.6 Discussion—In pumps incorporating two or more rotors operating at different speeds, the displacement is the volume displaced per revolution of the driving rotor. Displacement depends only on the physical dimensions of the pumping elements.

3.1.7 dry operation, \( n \)—a brief run during priming or stripping with suction and discharge lines unrestricted and pump chamber wet with liquid but pumping only air or vapor available from the suction.

3.1.8 efficiency, mechanical, \( n \)—the ratio of the pump power output (hydraulic horsepower) to the pump power input (brake horsepower) expressed in percent.

3.1.9 efficiency, volumetric, \( n \)—the ratio of the pump’s capacity to the product of the displacement and the speed expressed in percent.

3.1.10 fuel, clean, \( n \)—fuel purified for direct use.

3.1.11 fuel, dirty, \( n \)—fuel before purification that may contain water and some solids.

3.1.12 net positive inlet pressure available (NIIPA), \( n \)—the total inlet pressure available from the system at the pump inlet connection at the rated flow, minus the vapor pressure of the liquid at the pumping temperature.

3.1.13 net positive inlet pressure required (NIIPR), \( n \)—the net pressure above the liquid vapor pressure at rated flow and pumping temperature and at the pump inlet connection required to avoid performance impairment due to cavitation.

3.1.14 pressure, cracking, \( n \)—sometimes called set pressure, start-to-discharge pressure, or popping pressure; the pressure at which the relief valve just starts to open.

3.1.15 Discussion—This pressure cannot be determined readily in a relief valve that bypasses the liquid within the pump.

3.1.16 pressure, differential, \( n \)—the difference between discharge pressure and inlet pressure.

### TABLE 1 Pump Sizes

<table>
<thead>
<tr>
<th>Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacity (gpm)</td>
<td>10</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>Maximum capacity (gpm)</td>
<td>13</td>
<td>30</td>
<td>59</td>
<td>86</td>
<td>114</td>
<td>221</td>
<td>328</td>
<td>433</td>
</tr>
<tr>
<td>Flange rating (lb)</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

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14 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
15 Available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096.
17 Available from American Gear Manufacturers Association, Suite 1000, 1901 N. Fort Myer Dr., Arlington, VA 22209.
18 Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
3.1.17 **pressure, discharge, n**—the total pressure at the outlet of the pump; discharge pressure is sometimes called outlet pressure.

3.1.18 **pressure, inlet, n**—the total pressure at the inlet of the pump. Inlet pressure is sometimes called suction pressure.

3.1.19 **pressure, maximum allowable working, n**—the maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified temperature.

3.1.20 **Discussion**—This pressure should not be greater than two thirds of the hydrostatic test pressure of the pressure containing parts.

3.1.21 **rated condition, n**—defined by discharge pressure, inlet pressure, capacity, and viscosity.

3.1.22 **rotary pump, n**—a positive displacement pump consisting of a casing containing gears, screws, lobes, cams, vanes, shoes, or similar elements actuated by relative rotation between the drive shaft and the casing.

3.1.23 **Discussion**—There are no inlet and outlet valves. The rotors are characterized by their close running clearances.

3.1.24 **slip, n**—the quantity of fluid that leaks through the internal clearances of a rotary pump per unit of time.

3.1.25 **Discussion**—Slip depends on the internal clearances, the differential pressure, the characteristics of the fluid handled and in some cases, the speed.

3.1.26 **speed, maximum allowable, n**—in revolutions per minute, the highest speed at which the manufacturers’ design will permit continuous operation.

3.1.27 **speed, minimum allowable, n**—in revolutions per minute, the lowest speed at which the manufacturers’ design will permit continuous operation.

3.1.28 **speed, rated, n**—the number of revolutions per minute of the driving rotor required to meet the rated conditions.

3.1.29 **suction lift, n**—a term used to define a pump’s capability to induce a partial vacuum at the pump inlet.

3.1.30 **temperature, maximum allowable, n**—the maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure.

3.1.31 **unit, pump, n**—the pump and motor assembly; it also includes a gear box, base, couplings, guards, as required.

### 4. Classification

4.1 Pumps shall be classified as follows:

4.1.1 **Types:**

4.1.1.1 **Type II**—Screws with timing gears.

4.1.1.2 **Type III**—Screws without timing gears.

4.1.1.3 **Type IV**—Impellers with timing gears.

4.1.1.4 **Type V**—External gear (spur, helical, herringbone, lobe).

4.1.1.5 **Type VIII**—Internal gear, internal rotary lobe.

4.1.1.6 **Type X**—Vane (sliding).

4.1.1.7 **Type XI**—Sliding shoe.

4.1.2 **Sizes:**

4.1.2.1 Standard pump sizes shall be as shown in Table 1. Rated capacity shall be based on 150-psig discharge pressure, 10-psig inlet pressure and 32-SSU viscosity (1034-kPa gage, 69 kPa absolute, and 2 centistoke, respectively). Rated capacity equals the minimum capacity. The maximum capacity shall not exceed the amount determined by the following formula:

\[ Q_{\text{max}} = Q \left[ 1 + \frac{1}{1 + G^4} \right] \]  

where:

\[ Q = \text{the rated capacity (minimum capacity)} \]  
\[ Q_{\text{max}} = \text{maximum allowable capacity, at 32-SSU viscosity} \]

4.1.2.2 **Discussion**—The minimum capacity shall be rounded to nearest whole number.

4.1.2.3 **Discussion**—The maximum capacity shall not exceed the amount determined by the following formula:

\[ Q_{\text{max}} = Q \left[ 1 + \frac{1}{1 + G^4} \right] \]  

where:

\[ Q = \text{the rated capacity (minimum capacity)} \]  
\[ Q_{\text{max}} = \text{maximum allowable capacity, at 32-SSU viscosity} \]

### 5. Ordering Information

5.1 The ordering activity is to provide the following information to the potential bidders:

5.1.1 **Title, number, and date of specification.**

5.1.2 **Type and size of each pump (see Section 4).**

5.1.3 **Quantity of each pump type and size (see Table 1).**

5.1.4 **Mounting configuration (vertical, horizontal).**

5.1.5 **Motor characteristics and specifications (see 7.6 and motor specification if applicable).**

5.1.6 **Discharge pressure.**

5.1.7 **System relief valve cracking pressure and full flow bypass pressure (see 7.6 and 7.15).**

5.1.8 **Preservation, packaging, packing, and boxing requirements (see Section 14).**

5.1.9 **Quantity of drawings (see 13.2).**

5.1.10 **Quantity of manuals (see 13.3).**

5.1.11 **Format and quantity of each type of test report (see 12.1.1.4 and S12.3.8).**

5.1.12 **Shock, noise, and vibration requirements, if applicable (see S12.3).**

5.1.13 **Types of certified data required (see 12.1.2).**

5.1.14 **Instruction plates and locations, if required.**

5.1.15 **Define shipbuilding specification, if applicable (see 13.1).**

### 6. Materials

6.1 Pump component parts shall be constructed of the materials shown in Table 2.

### 7. General Requirements

7.1 **Pumps shall be designed to pump distillate fuel and aviation turbine fuel with a viscosity range of 32 to 100 SSU (2 to 21 cSt).**

7.2 Pumps shall be capable of sustained operation during inclinations up to 45° in any direction.

7.3 The pumps shall be capable of withstanding environmental vibration induced by shipboard machinery and equipment in the frequency range of 4 to 25 Hz.

7.4 The internally excited vibration levels of the pump shall not exceed 0.003-in. (0.076-mm) displacement peak to peak during rated operation when readings are measured on the pump case near the coupling perpendicular to the pump shaft.

7.5 At the conditions in 4.1.2, the airborne noise level of the pump unit shall meet the requirements in Table 3.

7.6 The pump shall be driven by an electric motor. The driver shall be sized for maximum flow at the relief valve full flow bypass pressure, at maximum viscosity.
7.7 If a reduction gear is required between the driver and the pump, it shall be provided by the pump manufacturer. Reduction gears shall meet the requirements of the American Gear Manufacturers Association Gear Handbook Volume 1, AGMA 390.03. Minimum acceptable gears are AGMA Class 7 and minimum acceptable pinions are AGMA Class 8. Bearings shall be designed for a minimum L10 life of 15,000 h.

7.8 All pump units shall incorporate guards over couplings, belts, and other external rotating parts. The guards shall prevent personnel contact with the rotating elements. Guards shall be rigid enough to support a 200-lb (88-kg) person standing on it.

7.9 The seating surfaces of mounting bedplates, bracket mounting plates, or other mounting arrangements shall be machined.

7.10 Mounting bedplates, brackets, and plates shall be provided with holes of sufficient size and quantity to ensure adequate attachment to shipboard foundation or mounting structure. Means shall be provided for attaching lifting gear for installation or removal.

7.11 Vertical units with face mounted motors shall be arranged so there are four possible orientations of motor driver to pump. Other drivers are to be oriented per the ordering data.

7.12 Vertical units that are motor driven shall be assembled with the conduit box mounted over the pump inlet flange, unless otherwise specified.

7.13 Couplings between pump and driver shall be keyed to both shafts.

---

**TABLE 2 Materials**

<table>
<thead>
<tr>
<th>Component</th>
<th>Materials</th>
<th>Specification (UNS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casings, heads and covers</td>
<td>Aluminum bronze</td>
<td>B 148 (C95800)</td>
</tr>
<tr>
<td></td>
<td>Leaded tin bronze</td>
<td>B 584 (C93700)</td>
</tr>
<tr>
<td></td>
<td>Stainless steel, precipitation hardening</td>
<td>A 747/A 747M</td>
</tr>
<tr>
<td>Shafts</td>
<td>Ni-Cu-Al alloy (Monel K-500)</td>
<td>AMS 4676, AMS 4677 (N05500)</td>
</tr>
<tr>
<td>Rotors</td>
<td>Stainless steel</td>
<td>A 564/A 564M (S17400)</td>
</tr>
<tr>
<td></td>
<td>Aluminum bronze</td>
<td>B 150 (C63000)</td>
</tr>
<tr>
<td></td>
<td>Leaded tin bronze</td>
<td>B 584 (C93700)</td>
</tr>
<tr>
<td></td>
<td>Ni-Cu-Al alloy (Monel K-500)</td>
<td>AMS 4676, AMS 4677 (N05500)</td>
</tr>
<tr>
<td></td>
<td>Austenitic stainless steel</td>
<td>A 276 (S21800)</td>
</tr>
<tr>
<td></td>
<td>Stainless steel, precipitation hardening</td>
<td>A 564/A 564M (S17400)</td>
</tr>
<tr>
<td>Rotor housings, liners, and disks</td>
<td>Leaded tin bronze</td>
<td>B 584, B 505, or B 271 (C93700)</td>
</tr>
<tr>
<td></td>
<td>Stainless steel, precipitation hardening</td>
<td>A 564/A 564M, A 747/A 747M (S17400)</td>
</tr>
<tr>
<td></td>
<td>Stellite</td>
<td>AMS 5894</td>
</tr>
<tr>
<td>Glands</td>
<td>Stainless steel</td>
<td>A 743/A 743M Gr. CF8M (J92900)</td>
</tr>
<tr>
<td></td>
<td>Tin bronze</td>
<td>B 584, B 271, or B 505 (C90300)</td>
</tr>
<tr>
<td>Bedplates and brackets</td>
<td>Aluminum</td>
<td>B 209 Gr. 5086, B 221 Gr. 5086</td>
</tr>
<tr>
<td></td>
<td>Steel pipe</td>
<td>A 53/A 53M, A 106</td>
</tr>
<tr>
<td></td>
<td>Stainless steel</td>
<td>A 240/A 240M, A 269, A 312/A 312M</td>
</tr>
<tr>
<td></td>
<td>Structural steel</td>
<td>A 36/A 36M</td>
</tr>
<tr>
<td>Timing gears</td>
<td>Nitrided steel</td>
<td>A 434 Gr. 4140, C1.BC</td>
</tr>
<tr>
<td></td>
<td>Stainless steel</td>
<td>A 582/A 582M (S41600)</td>
</tr>
<tr>
<td>Studs, bolts, hex head cap screws</td>
<td>Medium carbon and alloy steel</td>
<td>A 449, A 193/A 193M Gr. B7, A 354 Gr. BD</td>
</tr>
<tr>
<td></td>
<td>Austenitic stainless steel (304/316)</td>
<td>A 193/A 193M Gr. 8/8M, F 593 Grp. 1 or 2</td>
</tr>
<tr>
<td></td>
<td>Ni-Cu alloy</td>
<td>F 468 (N04400)</td>
</tr>
<tr>
<td></td>
<td>Ni-Cu-Al alloy</td>
<td>F 468 (N05500)</td>
</tr>
<tr>
<td>Socket head cap screws</td>
<td>Alloy steel</td>
<td>A 574</td>
</tr>
<tr>
<td></td>
<td>Austenitic stainless steel</td>
<td>F 837, Grp. 1</td>
</tr>
<tr>
<td>Socket set screws</td>
<td>Alloy steel</td>
<td>F 912</td>
</tr>
<tr>
<td></td>
<td>Austenitic stainless steel</td>
<td>F 880</td>
</tr>
<tr>
<td>Nuts, hex</td>
<td>Carbon steel</td>
<td>A 563, Gr. B</td>
</tr>
<tr>
<td></td>
<td>Medium carbon steel, quenched and tempered Austenitic stainless steel</td>
<td>A 194/A 194M Gr. 8/8M, A 563 Gr. DH (equiv. Gr. 8)</td>
</tr>
<tr>
<td></td>
<td>Ni-Cu alloy</td>
<td>F 467 (N04400)</td>
</tr>
<tr>
<td>Flange nuts, hex</td>
<td>Carbon steel</td>
<td>A 563</td>
</tr>
<tr>
<td></td>
<td>Self-locking hex nuts, nylon inserts Carbon steel</td>
<td>A 563, Gr. DH (equiv. SAE Gr. 8) and MIL-N-25027</td>
</tr>
<tr>
<td></td>
<td>Austenitic stainless steel</td>
<td>F 594, Grp. 1 or 2 and MIL-N-25027</td>
</tr>
<tr>
<td>O-rings and other elastomers</td>
<td>Fluorocarbon (Viton, Fluorel, or equal)</td>
<td>D 1418 Class: FKM, MIL-R-83248, D 2000</td>
</tr>
<tr>
<td></td>
<td>Type and Class: HK</td>
<td>Type and Class: HK</td>
</tr>
<tr>
<td>Gaskets</td>
<td>Plant and animal fiber</td>
<td>D 104, I.D. No. P 3313B</td>
</tr>
<tr>
<td></td>
<td>Fluorocarbon</td>
<td>D 1418 Class: FKM, D 2000</td>
</tr>
<tr>
<td>Vanes and shoes</td>
<td>Nitrile (Buna-N or equal)</td>
<td>AMS 3215</td>
</tr>
<tr>
<td></td>
<td>Leaded tin bronze</td>
<td>B 584 (C93700)</td>
</tr>
<tr>
<td></td>
<td>Thermoset composite</td>
<td>None</td>
</tr>
</tbody>
</table>

**TABLE 3 Acceptable Octave Band Sound Pressure Levels (in dB re 20 µPa)**

<table>
<thead>
<tr>
<th>Octave Band Center Frequency, Hz</th>
<th>31.5</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>91</td>
<td>88</td>
<td>85</td>
<td>82</td>
<td>79</td>
<td>76</td>
<td>73</td>
<td>70</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

7.7 If a reduction gear is required between the driver and the pump, it shall be provided by the pump manufacturer. Reduction gears shall meet the requirements of the American Gear Manufacturers Association Gear Handbook Volume 1, AGMA 390.03. Minimum acceptable gears are AGMA Class 7 and minimum acceptable pinions are AGMA Class 8. Bearings shall be designed for a minimum L10 life of 15,000 h.

7.8 All pump units shall incorporate guards over couplings, belts, and other external rotating parts. The guards shall prevent personnel contact with the rotating elements. Guards shall be rigid enough to support a 200-lb (88-kg) person standing on it.
8. Pump Design

8.1 The pump inlet and outlet connections shall be flanged. Nonferrous material flanges shall be in accordance with ANSI B16.24 flat face, unless otherwise stated in the ordering data. Spool piece adapters (threaded and seal welded, or O-ring sealed to the pump case on one end and flanged on the other end) may be furnished to meet the flanged inlet and outlet requirement.

8.2 The pump cases shall be equipped with vent, drain, inlet, and outlet gage connections. The connection shall be straight thread with O-ring seal. Tapered pipe thread connections are prohibited. Small pumps do not require these connections.

8.3 The pumps shall be equipped with radial and thrust bearings as necessary to counteract any unbalanced forces in the pump and to ensure that the pump will operate satisfactorily under the conditions stated in 7.2.

8.4 The bearings shall be securely fitted (by snap rings or shoulders or other means) to prevent axial movement. Bearing housings shall be integral to the pump case or secured to the pump case in such a manner as to ensure alignment. Usage of bolts alone is not considered sufficient to ensure alignment.

8.5 The bearings may be sealed and self or externally lubricated or may be lubricated by the liquid being pumped.

8.6 The rolling contact bearings shall be selected in accordance with AFBMA standards and shall have a minimum L10 life of 15,000 h as calculated in accordance with AFBMA Standard 9 or 11 as appropriate.

8.7 The pumps shall be equipped with mechanical shaft seals in accordance with Specification F 1511. The installation shall ensure that adequate circulation of liquid at the seal faces occurs to minimize deposit of foreign matter and to provide adequate lubrication of the seal faces.

8.8 The mechanical seals shall be positioned or located on the shaft axially, by a positive means such as a stub, step, or shoulder positively located on the pump shaft. Set screws shall not be used to position seals or seal sleeves axially. An antirotation pin shall be provided for shaft sizes 1 in. and larger to prevent the mechanical seal-mating ring from rotation, if required by the ordering document.

8.9 The pump head or end covers, or both, shall be located to the pump case by a means such as rabbet, dowels, or pilot to ensure proper alignment.

8.10 The rotors and timing gears shall be machined and positively secured in position to maintain required clearances and prevent undue wear.

8.11 The fasteners shall be selected from Table 2, taking into consideration temperature of operation, mechanical properties, and corrosion resistance.

8.12 The pumps shall be provided with removable liners in pump sizes “C” or larger.

9. Performance Requirements

9.1 Pumps of each size shall deliver a capacity within the respective ranges shown in Table 1 when tested at 10-psia (69-kPa absolute) inlet pressure, 150-psi (1034-kPa) discharge pressure, and a fluid viscosity of 32 SSU.

10. Painting and Coatings

10.1 Painting—External unmachined and nonmating machined surfaces shall be thoroughly cleaned and painted with a fuel resistant, anticorrosive (lead and chromate free) primer and topcoat.

10.2 Painting external surfaces of nonferrous parts and components is not required but is permissible to avoid excessive masking. Identification and information plates should not be painted or over sprayed.

11. Equipment Identification Plates

11.1 The identification plates shall be made of brass or stainless steel and furnished on each pump unit.

11.2 The plates shall be secured to equipment with corrosion-resistant metallic fasteners.

11.3 The pump unit identification plates shall contain data as follows:

11.3.1 Manufacturer’s name.

11.3.2 Manufacturer’s model and type size.

11.3.3 Service application.

11.3.4 Manufacturer’s serial number.

11.3.5 Salient design characteristics if applicable.

11.3.5.1 Capacity.

11.3.5.2 Discharge pressure.

11.3.5.3 Pump rated speed (r/min).

11.4 Accessory units, such as the driver and gearbox, shall have an identification plate in accordance with the applicable equipment specification. If not specified, the manufacturer shall use its commercial nameplate.

12. Testing Requirements

12.1 The pump manufacturer shall perform the following tests at the manufacturing facility or approved test facility. Equipment for specified tests shall be provided by the manufacturer.

12.1.1 Performance Acceptance Tests—Each pump shall meet the following performance acceptance tests.

12.1.1.1 Mechanical Running Test—The pump shall be tested at rated condition of 150-psig discharge pressure, 10-psia inlet pressure, and 32 (+13/ −0) SSU viscosity to demonstrate that the pump is capable of delivering the required capacity as shown in Table 1.

12.1.1.2 Noise Tests—For pumps provided with drivers (units), each unit shall be tested to demonstrate the ability to meet the requirements of 7.5, if required by 5.1. The unit shall be operated at the discharge pressure (5.1.6) for these tests.

12.1.1.3 Hydrostatic Tests—Pressure-containing parts or the entire pump shall be tested hydrostatically with liquid to 225 psig for 10 min. The assembled pump shall be hydrostatically tested to 50 psig for 5 min. The tests shall be considered
satisfactory when no leaks are observed. Seepage past blanking plates and seepage of other sealing apparatus to perform the test is allowed. Operation of the hydrostatic test pump to maintain pressure is acceptable.

12.1.1.4 Test Reports—A test report shall be submitted for each test conducted. Quantity and format as defined in the ordering data.

12.1.2 Certified Data—Certified performance data shall be supplied when required. Testing and reporting as defined by ANSI/HI 3.6 for Type IV, Level A tests. See 5.1.13.

13. Technical Documents

13.1 General—Drawings and technical manuals shall be submitted in an electronic format that is ISO 9066 compliant. When this specification is invoked in a shipbuilding specification, the shipbuilding specification shall take precedence for technical documentation requirements. When this specification is used for spares, replacements, or requirements without technical documentation requirements, the following paragraphs apply.

13.2 Drawings:

13.2.1 Unit Drawings—An outline or top drawing of the unit (pump and driver) shall be furnished. Length, width, height, mounting details, and connections shall be dimensioned. Brackets, bedplates, guards, couplings, identification plates, rotation arrows, and so forth shall be shown on the drawing. The weight and center of gravity (calculated or actual) of the unit shall be indicated on the drawing.

13.2.2 Pump Drawings—Pump drawings shall include a sectional assembly drawing. The sectional assembly drawing shall contain a complete list of materials or reference to a list of materials drawing, which shall be provided. Any subassembly made up of parts that require special alignment or assembly methods that cannot be disassembled, repaired, and reassembled onboard ship without the use of special tools and jigs shall be indicated as a subassembly in the list of material. The weight and center of gravity (calculated or actual) of the pump shall be indicated on the drawing.

13.2.3 Associated Equipment Drawings—Drawings for driver and associated equipment shall be in accordance with their respective specifications.

13.2.4 Performance Curves—Complete performance curves shall be furnished. The curves may be on graphs that can be printed on notebook size paper. Format as defined by ANSI/HI 3.6.

13.3 Technical Manuals—Instruction books or technical manuals shall be prepared for each different type or size of pump installed. A single manual shall contain not more than one type or size of pump. However, when several pumps are installed in a ship that are identical except for type of driver, they may be included in a single manual. Piece (item or find) numbers of parts referred to in technical manuals shall match the piece numbers shown on pump drawings. Technical manuals shall contain reproductions of pump drawings.

14. Packaging and Preservation

14.1 Packaging—Pumps, pump units, and accessories shall be packaged per Practice D 3951 for warehouse storage and the following:

14.1.1 Packaging for Domestic Shipment—Pumps, components, and units to be used within six months may be packaged using standard commercial packaging. For storage of greater than six months or when multiple handlings are anticipated, package to ensure prevention of pilferage and resistance to damage from multiple handlings.

14.1.2 Packaging for Overseas Shipment—Packaging and marking for overseas shipments shall include sufficient protection from adverse atmospheric conditions and exposure to worst case handling and storage problems. All products shall be protected with water-resistant packaging material for the exterior shipping container, either treated corrugated cartons or boxes built from mildew resistant lumber, depending on the weight of the product or the configuration of the load.

14.2 Preservation—Items susceptible to deterioration or damage from environmental elements shall be preserved. Noncoated ferrous surfaces shall be preserved.

14.3 Cushioning and Bracing—Items susceptible to damage during shipment and handling shall be cushioned or shall be securely braced or blocked, or both, within the shipping container, to avoid damage.

14.4 Container Marking—Containers, boxes, or packages shall be clearly marked with the ship to address, contract or purchase order number, shipping point address, item nomenclature, and bar codes. The lifting points and orientation markings shall be clearly visible.

15. Quality Requirements

15.1 The manufacturer shall have a certified ISO 9001 quality system.

16. Keywords

16.1 distillate fuel pump; fuel pump; positive displacement pump; pump; rotary pump
The following supplementary requirements established by the U.S. Navy, Commander Naval Sea Systems Command (NAVSEA) shall apply when specified in the contract or purchase order. When there is a conflict between the specifications and this Supplement, requirements of the Supplement shall take precedence.

S6.2 Materials other than shown in Table 2 are considered exceptions and are subject to approval by NAVSEA.

S7.3 The pumps shall be capable of withstanding environmental vibration induced by shipboard machinery and equipment in the frequency range of 4 to 25 Hz and be in accordance with MIL-STD-167-1 Type I. Maximum single frequency displacement (double amplitude) in the 4- to 15-Hz range is 0.060 in. (1.524 mm) and in the 16- to 25-Hz range is 0.040 in. (1.016 mm).

S7.4 The internally excited vibration levels of the pump shall be in accordance with MIL-STD-167-1 Type II and shall not exceed 0.003-in. (0.076-mm) displacement peak to peak during rated operation when readings are measured on the pump case near the coupling perpendicular to the pump shaft.

S7.5 At the conditions in 4.1.2, the airborne noise level of the pump unit shall meet the requirements in Table 3 (see MIL-STD-740-1).

S7.6 At the conditions in 4.1.2, the structureborne noise level of the pump unit shall meet the requirements in Table S1.1 (see MIL-STD-740–2).

S7.19 Pumps shall meet the requirements of MIL-S-901 HI (High Impact) Shock, Grade A.

S8.7 Mechanical shaft seals shall be in accordance with Specification F 1511, including Supplement S1.

### TABLE S1.1 Acceptable Structureborne Vibratory Acceleration Acceptance Criteria in AdB re 10 µm/s² (Reference MIL-STD-740-2)

<table>
<thead>
<tr>
<th>Octave Band Center Frequency in Hz</th>
<th>31.5</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resiliently mounted pumps</td>
<td>85</td>
<td>88</td>
<td>90</td>
<td>93</td>
<td>95</td>
<td>98</td>
<td>100</td>
<td>103</td>
<td>105</td>
</tr>
<tr>
<td>Solidly mounted pumps</td>
<td>65</td>
<td>68</td>
<td>70</td>
<td>73</td>
<td>75</td>
<td>78</td>
<td>80</td>
<td>83</td>
<td>85</td>
</tr>
</tbody>
</table>

S12.3 Qualification Tests—The first pump of each size, type, or design shall meet the following qualification tests. All tests shall be performed with the motor size required at rated condition as indicated in 4.1.2.

S12.3.1 Performance Test—The pump shall be tested at rated condition of 150-psig discharge pressure, 10-psia inlet pressure, and 32 (+13/−0) SSU viscosity to demonstrate that the pump is capable of delivering the required capacity as shown in Table 1. Record all test data, including electrical power input, for comparison to performance retest results (see S12.3.7).

S12.3.2 Vibration Type II Test—The pump shall be tested to demonstrate the ability to meet the requirements of S7.4. Record all test data, including electrical power input, for comparison to performance retest results (see S12.3.7).

S12.3.3 Noise Tests—The pump shall be tested to demonstrate the ability to meet the requirements of S7.5 and S7.6. Record all test data, including electrical power input, for comparison to performance retest results (see S12.3.7).

S12.3.4 Vibration Type I Test—The pump shall be tested to demonstrate the ability to meet the requirements of S7.3.

S12.3.5 Shock Test—The pump shall be tested to demonstrate the ability to meet the requirements of S7.19.

S12.3.6 Endurance Test—The endurance test shall consist of a running test of not less than 500 h of actual running time at rated condition. The 500 h shall be broken by at least three rest periods of 8 h or more each. A minimum of ten start-stop cycles shall be performed during the course of the test.

S12.3.7 Performance Retest—Upon completion of the tests in S12.3.1 through S12.3.6, repeat the performance test (S12.3.1), the vibration type II test (S12.3.2), and the noise test (S12.3.3). Record all test data.

S12.3.8 Test Reports—A test report shall be submitted for each test conducted. Quantity and format as defined in the ordering data.
Standard Guide for
Marine Vessel Structural Inspection Considerations

This standard is issued under the fixed designation F 1754; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers information to develop and implement a marine vessel inspection process. It is intended to provide considerations for persons interested in planning, organizing, and implementing a structural survey plan for a marine vessel, especially during the design phase of the vessel. It is intended to be used in conjunction with any other required inspection or survey requirements but can form the basis for such planning in the absence of other such applicable requirements.

1.2 This guide provides owners, operators, shipyards, and designers with a plan for developing a detailed inspection process that covers all stages of the operating life of a marine vessel, including the design, construction, and in-service periods. This plan may be developed and used in concert with classification society and flag state surveys and inspections.

1.3 This guide also provides the basis for development of a recommended corrective action plan for typical structural deficiencies or deviations, or both.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.5 All portions of this guide may not be applicable to all vessels or shipyards since many yard-specific standards to ensure contracted level of quality are in existence.

2. Referenced Documents

2.1 ASTM Standards:  

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 blind spots, n—areas of a vessel’s structure that cannot be visibly or electronically inspected for failure.

3.1.2 large tanks, n—tanks of such dimension as to have uninspectable heights greater than 10 m.

3.1.3 telltale areas, n—areas of a ship’s structure identified by analyses and investigations during design development as being subject to higher stresses or more susceptible to fatigue than others, even though the higher stresses are still within allowable limits. Also, areas identified after the vessel is placed in service that continue to experience active or recurring cracking in the watertight envelope or that affect the structural integrity of the vessel.

4. Introduction

4.1 As stated earlier, the intent of this guide is to assist in the preparation of an inspection plan for a marine vessel during its design, construction, and in-service stages and to plan for inspection during the design. This guide should be used in the preparation of a specific inspection program for the construction of a specific marine vessel. It is not intended to set any stringent requirements for the structural inspections of any particular vessel. The suggestions for various inspection considerations in this guide are presented for the purpose of making available for review and use a broad set of guidelines.

4.2 This guide is applicable to all commercial and pleasure marine vessels. Although the references generally apply to steel and aluminum welded hulls, the overall aspects may be applied to any material or type of construction.

4.3 At any point of its construction or service life, the vessel may require classification society or flag state regulatory inspections, or both, as well as shipowner’s surveys. The surveys, depending on occasion, should consider the general condition of the vessel, provide a detailed condition assessment, obtain data to determine corrosion rate and damage, or obtain information for repair specification development, or a combination thereof. The inspection plan should take into account all of these types of information in its development. On occasions, the surveys also should obtain data on rate of coating breakdown.

4.4 Because of severe loadings, excessive wastage, poor structural design, improper use of materials, excessive fatigue cycling, and so forth, failure may occur at any structure component at some stress value that is much less than the theoretically allowable limit. Therefore, detection of such
conditions by careful analysis and by sufficient inspection throughout the entire process is consequently crucial for the prevention of failure. This guide describes generically the extent of and the procedures for inspections to be performed at each stage of a marine vessel’s life. Minor and major imperfections can be detected early in the construction process. Therefore, structural integrity can be maintained with periodic in-service inspections and appropriate and timely corrective measures to prevent any accumulation of defects or costly rework.

4.5 From construction and early service life inspections, a structural history of the vessel can be prepared forming the basis on which future in-service inspection results can be evaluated.

5. Inspection Considerations During Design Stages

5.1 To ensure the marine vessel’s structural integrity, the designers should consider the following inspection-related requirements during the design stages:

5.1.1 Inspectability of a Marine Vessel’s Structure During Construction and In-Service:

5.1.1.1 Background—During the life of any marine vessel, several inspections are conducted on the structure. These consist of two types that directly reflect their purpose, convenience and regulatory. In conducting either one, certain locations require access that are not readily accessible without climbing the structure or obtaining assistance from mechanical devices. When an inspection requires the use of mechanical means to access the structure, several options are available. They include anything from a simple platform elevated by a hoist connected at the overhead to a sophisticated ROV (Remote Operated Vehicle) that permits the inspector to remain outside the tank altogether. An issue that must be recognized is the definition of the “degree of inspection” has a direct bearing on the conclusions drawn from information presented herein.

5.1.1.2 For the purposes of this guide, the following assumptions are made relative to the degree of inspection:

5.1.1.3 The inspected structure must be in direct line of sight.

5.1.1.4 The inspected structure must be in clear and distinct view, taken as a distance of not more than 1.5 m (5 ft) from one’s eyes.

5.1.1.5 The structure is to be inspected to a degree that would reveal almost all fractures that have a length of 50 mm (2 in.) or more. This depends significantly on the cleanliness, lighting level, stress, and so forth, of the structure.

5.1.1.6 The inspection shall be conducted in a continuous manner such that the shortest amount of time is taken for it.

5.1.1.7 For the purposes of inspection, the structure should be broken down into discrete zones, such as those depicted in Fig. 1. Where the structure differs from that depicted in Fig. 1, an appropriate scheme of identifying zones for inspection should be adopted.

(1) Zone 1—The bottom and inner bottom shell structure including the turn of bilge and any structure attached to them.

(2) Zone 2—The deckhead structure, from ship’s side to ship’s side, including the stiffening attached to it.

(3) Zone 3—The side shell structure, including the side bulkhead structure for double hull vessels, including the stiffening attached to it.

(4) Zone 4—The longitudinal bulkhead structures that include the centerline and side longitudinal bulkheads, except a side bulkhead of a double hull structure.

(5) Zone 5—The transverse bulkhead structure, fore and aft sides, extending from the bottom shell to the deckhead.

5.1.2 Access Methods:

5.1.2.1 Fixed Staging—This method consists of poles, fittings, planks, and ladders that create a tower or walkway. This is the only method that permits access to all structural areas of a vessel. To achieve this coverage, however, it is very expensive and time consuming. A simple description of the method could be compared to an erector set. It is a straightforward method to which most people can relate. It may be a method that more people feel comfortable using than some. Accessing a deckhead structure that is 20 m (66 ft) or so above the bottom, however, is not a place for anybody with a fear of heights. This method has been a standard access method for conducting inspections and repairs to vessels for many years. The components are better designed and lighter in weight than ten or more years ago. Therefore, it is more easily constructed today.

5.1.2.2 Portable Staging—This method consists of a platform of sufficient size to carry at least one person. It also includes a winch that is attached to the platform. The wire on the winch is connected to the underdeck structure so that the platform raises towards the wire’s connection point at the underdeck. The size of the platform varies. Some are sized to lift only one person while others are sized to lift up to four or five persons. In fact, some platforms are similar to those used by window washers—lightweight and breakdown for portability. For industrial applications, the staging is built more rugged.
than typically used for window washers, such that the design load is higher. Persons on the staging should have individual safety harnesses attached to them. The Occupational Safety and Health Administration (OSHA) has become more active in verifying contractors perform their work in a safe manner. One high-risk aspect of using this staging is attaching the lifting wires to the overhead. This normally is accomplished by a person walking the deckhead. This person uses a set of stirrups each attached to one end of a short length of wire with some type of hook at the opposite end. The hooks fasten into the deckhead structure, then a person proceeds to walk across the deckhead while moving the stirrups and connecting the platform’s lifting wires to the deckhead. OSHA has become more aware of this activity due to fatalities. They now require these persons to wear safety harnesses connected to lifelines. An alternate method of attaching the lifting wires to the overhead, but not normally used, is by drilling holes into the deck and passing wires through them. The wire end is then secured to provide a holding point. The problem is that drilling holes into a deck is not a desired situation. It can become a source of future fracture problems if not properly done and might be located in an area of high stress.

5.1.2.3 Rafting—This is a straightforward system and may be the easiest to understand. It consists simply of rowing around in a rubber raft while the water level in the tank is changed in height. This method has been used for many years, not only for inspection reasons, but also for access to upper regions of a tank by the vessel’s crew for conducting repairs. In fact, there are various objects that can be used to provide buoyancy when access to high areas in a tank is needed and a rubber raft is not available. For structural inspections, normally two persons occupy a raft; this enhances the raft’s maneuverability and the inspection. All areas of the structure can be accessed easily from the level of the liquid. Vessels with deep transverse structures, however, prohibit safely accessing the deckhead structure. If the water rises, it traps the raft’s occupants between the structure and water level without a safe exit from the tank. This applies to any tank with a deckhead structure to some degree. An important aspect of this method relating to the thoroughness of an inspection is the rate of water level change. If the intervals are too great, such as 5 m (16.5 ft), relating to the thoroughness of an inspection is the rate of water structure to some degree. An important aspect of this method exit from the tank. This applies to any tank with a deckhead occupying between the structure and water level without a safe transverse structures, however, prohibit safely accessing the platform’s lifting wires to the deckhead. OSHA has become more aware of this activity due to fatalities. They now require these persons to wear safety harnesses connected to lifelines. An alternate method of attaching the lifting wires to the overhead, but not normally used, is by drilling holes into the deck and passing wires through them. The wire end is then secured to provide a holding point. The problem is that drilling holes into a deck is not a desired situation. It can become a source of future fracture problems if not properly done and might be located in an area of high stress.

5.1.2.4 Climbing—This method often complements one of the other methods mentioned in the preceding sections. It varies from climbing the structure a short distance to see a particular location better, to climbing the height of the tank with the aid of a safety harness. The latter, although demonstrated, is not typically used. There are hazards when climbing any height; the higher one goes, the greater the risk of severe injury if one falls. Prudent judgment, therefore, is necessary to prevent accidents. This includes a decision to not climb to any height if the circumstances so indicate, for example, slippery conditions, physical problems, and so forth.

5.1.2.5 Other—The inspection methods here are not considered to be primary methods but rather ones that can support and enhance one or more of the methods previously described. They serve a specific purpose.

5.1.2.6 Ziggy—This mechanical device consists of a mechanism positioned above the deck that raises and lowers, and rotates from side to side, with a steel column constructed of short, rectangular tubes. The tubes are lowered through a butterworth hole to the bottom. A horizontal beam is attached to the bottom end of the column, and a single-person basket is attached to the other end of the beam. As the column is raised or lowered, the person in the basket can extend oneself to a distance between 3 and 9 m (10 and 30 ft) from the vertical column. This device permits one to inspect the side and underdeck structure without building a tower of staging, climbing the side shell, or filling the tank with water to the underdeck. It can be operated from the basket or from the deck positions.

5.1.2.7 Remote Operating Vehicle (ROV)—An ROV is similar to a miniature underwater, unmanned vehicle. This method also requires filling the tank with water. Unlike the rafting method, however, it is important to fill the tank as close to 100 % as possible. The ROV typically is sphere-like and has small, external propellers running inside ducts for maneuvering. They all include a camera. Some models are capable of doing additional operations other than viewing the tank internals, such as thickness gaging, cleaning off the surface, and varying the light intensity. An operator controls the ROV outside the tank at a control console. There is a monitor alongside to follow the maneuvers and to view the structure. A video tape of the whole inspection or parts thereof can be made. The communication link between the control panel and ROV is by cables connecting the two. It is important, therefore, to understand the compartment size and extent of inspection expected by the unit. The operator must understand the tank space where the ROV is operating. A knowledge of the internals, protruding obstacles, pipelines, and tank boundaries, therefore, is necessary to prevent the unit from becoming tangled in them.

5.1.2.8 Maricam—This unit could be considered a hybrid of the ROV and Ziggy methods. It consists of a high-resolution video camera mounted on a vertical column extended into the tank space from the deck. It too is remotely operated by two persons on deck who control the camera’s movement, the light intensity, the lens’ iris, zoom, and focus features; document suspect areas by video taping or manually logging the data; and monitor the video screen.

5.1.3 Identification of Telltale Areas in a Marine Vessel’s Structure:

5.1.4 Determination of standard tolerances and acceptable levels for structural deviations on the basis of how they affect the structural performance as agreed upon by the owner, classification society, flag state, and shipyard

5.1.5 Selection of a corrosion protection system, such as coatings and cathodic protection, that will best protect the structure for the intended service under the maintenance plan. The selection of coatings should consider, in addition to
protecting the structure, the ability to properly inspect the structure after a period of service.

5.2 **Inspectability**—In addition to the considerations of inspection methods in 5.1.1, the following precautions should be taken during design and preparation of detailed structural drawings:

5.2.1 Provide appropriate transverse and longitudinal member spacings and member depths to facilitate safe access.

5.2.2 Avoid blind spots in the structural arrangements.

5.2.3 Provide access plates or holes for entering tightly arranged structures. In addition to providing minimum sizes for openings, other considerations such as footholds, escape routes, alignment, and means of ventilation should be considered. In large tanks, catwalks should be considered in order to reduce the need for constructing staging for inspections. Resolution A.272(VIII), as amended by A.330(IX) gives specific details for accessways for inspection.

5.2.4 Coordinating the selection of coating systems with the type of inspection program for the vessel. If removal of coatings will be necessary for random visual inspections, an acceptable program should be established in advance with the flag state and classification society.

5.2.5 Providing access to structural items subject to periodic in-service inspections, such as installing permanent rungs to facilitate access to otherwise uninspectable areas. These precautions could preclude the necessity of installing costly staging during in-service inspections.

5.2.6 The main objective is to ensure that structural design facilitates in-service and shipyard inspections. Toward this goal, a thorough review of structural design drawings to ensure proper consideration was given for structural inspections, which should be accomplished prior to structural fabrication.

5.2.7 Use of structural members that facilitate proper application of coating, such as bulb flats or flat bars, where access for coating application and corrosion removal is limited.

5.3 **Inspection Plan**—An inspection plan should be prepared for the vessel under design on the basis of analyses and investigations performed during the design stages. The plan should:

5.3.1 Provide accessibility instructions for parts to be inspected.

5.3.2 Identify telltale areas that should receive special attention during inspection activities. A separate set of plans should be included to identify these telltale areas. Specific inspection requirements should be given. NVIC 15-91 includes in its enclosures (2) and (3) a breakdown of necessary information to document these telltale areas (referred to in this guide as “critical areas”).

5.3.3 Include a listing of all structural elements to be inspected, as well as the type and extent of inspections for each. A typical summary checklist for primary strength members is given in Table 1. This list should be expanded to cover all primary, secondary, and structural details, as applicable, to the specific vessel to be constructed.

5.3.4 Upon contract signing with a shipyard, the designer should list or reference the applicable standard used to develop structural tolerances and acceptable levels of deviation from these standards. The levels adopted should either be one of existing compilations or a modification of one suitable for use in negotiations with the prospective builders prior to signing a construction contract.

5.4 Guidance on standard tolerances and acceptable deviations can be obtained from classification society Rules, IHI SPAIS, Production Standards of the German Shipbuilding Industry, VIS 530 or SSC 213 (3, 4, 5, 6), as well as Guide F 1053/F 1053M. Most of these publications also contain recommended repair and corrective action procedures for major deviations from acceptable levels. These recommendations may be used as a baseline in determining the specific corrective action procedures to be adopted for the specific ship to be constructed.

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4 The boldface numbers in parentheses refer to the list of references at the end of this standard.
6. Inspection Activities During Construction

6.1 By specifying preplanned inspections in excess of what is necessary to ensure structural integrity of the completed vessel, a burden is imposed on the shipyards, and therefore, results in costs and delays to the owners. On the other hand, by specifying and then conducting an insufficient amount of inspection, some deficiencies in the structure may remain undetected and may result in added repair or renewal operations. Accordingly, agreement is needed on a reasonably balanced level of inspection among the parties concerned (shipowner, shipyard, classification society, flag state, and designer). The aforementioned inspection plan can serve as the vehicle for this agreement.

6.2 Owner’s Needs:

6.2.1 The owner of a vessel may need or desire to have conducted certain inspection activities and corrective measures that the shipyard may consider unnecessary or unwarranted from a structural strength viewpoint. An example is the desire of the owner of a high speed container ship to have all surface imperfections on the exterior hull plating, such as burrs, scars, spatter, removed even though these do not affect the ship’s structural integrity and could be considered as cosmetic repair. Such removal, however, is important to the shipowner in light of operational efficiency.

6.2.2 The owner also may have a preference for the type and extent of nondestructive examinations (NDE) to be employed in construction inspections in excess of that required by class or flag state requirements. In such instances, this preference must be clearly stated in the specification.

6.2.3 All the needs expressed by the owner should be discussed by the concerned parties and agreed-upon procedures made a part of the construction inspection plan.

6.3 Receipt Inspection of Materials:

6.3.1 Consideration should be given to the inspection of structural material upon arrival at the shipyard’s receiving area. Discussion with the class society, flag state authorities, the designer, and the shipyard should be conducted in order to determine any such inspection necessary, in addition to their requirements. Material certificates should always be confirmed with the material at delivery. Quality system procedures, in effect, may preclude intensive inspection with activity and record monitoring sufficing. During inspection of material, however, the following defects are those which must be spotted:

- Deviations from nominal dimensions.
- Surface defects, such as excessive pitting and flaking on plate and shape materials.
- Laminations on plates.
- Deviations from the specified type or grade of structural materials.

6.3.2 In order to detect these defects, visual inspections should be made and complemented by measurements for dimensional accuracy and by ultrasonic examinations to detect laminations as necessary. The extent of such examinations must be based on experience. In the last case, a review of mill certification for the plate is necessary.

6.3.3 Recommended tolerance standards and repair procedures for defects in excess of allowable levels are contained in Guide F 1053/F 1053M, SSC 273, and JSOS–Hull Part (7, 8). Repair procedures or acceptance criteria, or both, should be developed with classification society and flag state concurrence.

6.3.4 By reviewing these references, the minimum receipt inspection requirements should be established and included in the ship’s construction inspection program.

6.4 Construction Inspections:

6.4.1 In-process inspections should be performed by the shipyard production department supervisors as a self-inspection activity and by the quality assurance department inspectors for the purpose of assuring adequate control of quality during the ship construction process. The ship’s construction inspection program also should include notations as to the elements of construction required to be inspected by flag state and classification society representatives.

6.4.2 The specified procedures, methods, and organizational roles may vary depending on the shipyard where the construction will take place and on the type and size of the vessel to be constructed. In any case, however, particular visual inspection functions should be accomplished during specific stages of construction.

6.4.3 Visual inspections during subassembly, assembly, and erection stages shall examine carefully the structure with specific attention to the following:

6.4.3.1 Completeness—To make sure that all of the major structural and production members on the subassembly/assembly/module/ship are in place as required by the detail design drawing or in accordance with good marine practice if all areas are not addressed in the drawings.

6.4.3.2 Materials Used—To verify that only the correct materials as specified by the detail design drawings are used. Material identification color codes or markings can be used for this verification.

6.4.3.3 Accuracy—To pinpoint apparent deviations from specified dimensions with the purpose of assuring that subassemblies and assemblies fit together. A preplanned dimensional program is necessary with the purpose of assuring that subassemblies and assemblies fit together. A preplanned dimensional verification program is necessary to accomplish this.

6.4.3.4 Joint Preparation—To ensure accuracy in fit-up, root openings, alignment of members, cleanliness, removal of slag, beveling, and so forth.

6.4.3.5 Weld Layout—This layout is used to determine that weld sizes are correct and that continuous or intermittent welds, or both, are being used in accordance with the detail design drawings. Full penetration welds should be inspected from both sides.

6.4.3.6 Fairness—To observe any noticeably excessive unfairness in the completed unit for the purpose of requiring fairness measurements if necessary.

6.4.3.7 Structural Details—To verify compliance with design drawings of structural details such as clearance cutouts, collars, brackets, stiffener end connections, and so forth.

6.4.3.8 Supports/Braces—To verify that an adequate quantity and quality of supports, braces, and lifting pads are provided and properly located for use in moving and handling
the unit without damaging it or disturbing it, or both, to the point that alignment requirements are exceeded.

6.4.3.9 General Workmanship—To see that the completed structural unit is free of discontinuities, undercuts, weld pockets, sharp ragged edges, nicks, or other damage that may initiate or propagate cracks. To verify that all temporary fabrication/erection attachments that are not required during later stages of construction are properly removed if desired by the owner.

6.4.4 Detailed structural drawings, construction specifications, and the inspection plan prepared during the design process are the specific guidelines for use in judging the acceptability of structures on the basis of visual inspections. A lot depends on the knowledge and experience of the inspector. Whenever the inspector is in doubt as to the acceptability of any part of the inspection criterion, the inspector should refer to the standard tolerances and acceptable deviations contained in SSC 273, JSQS–Hull Part (7, 8), Guide F 1053/F 1053M, or IHI SPAIS (3), the specification or those that may be included in the ship’s inspection plan. If the inspector considers it necessary to have physical measurements or NDE made, the inspector should request them.

6.4.5 Dimensional accuracy and dimensional control activities should cover all stages of construction from mold loft to launching.

6.4.5.1 Mold Loft—Loft sheets, roll molds, furnace molds, and battens should be inspected for dimensional conformance and for completeness of detail with the latest revised detailed structural drawings. Steel tapes used in layouts and measurements should be inspected periodically for accuracy.

6.4.5.2 Plate Shop and Numerically Controlled Burning Area—In order to verify conformance with detailed structural plans, the following should be inspected during plate preparation:

1. Orientation of plate with respect to the molded line.
2. Center punching of frames, buttocks, and waterlines for dimensional accuracy. The centerline of the ship should be used as a master reference line.
3. Spacings and angularities of structural members.
4. Verification of a sufficient final cut allowance.
5. Bevels and collars, final dimensions, alignment, and fairness, after the final cut.

6.4.5.3 Subassembly/Assembly/Erection Areas—The following dimensional accuracy inspections should be accomplished during panel and subassembly fabrication, assembly/unit/module construction, and erection processes in platen areas, pre-outfitting areas, and in building basins or shipways:

1. Orientation of plate with regard to the molded lines.
2. Spacing and dimensions of frames, stiffeners, girders, headers, and so forth.
3. Alignment and fairness, conformance of welds with detail plans and specifications.
4. Squareness and distortion.
5. Ship’s principal dimensions (length, beam, depth).
6. Declivity and straightness of keel.

6.4.6 Alignment and Fairness—Excessive misalignment in structures may cause stress concentrations and, therefore, may lead to failure. Accordingly, alignment inspections should be made during all stages of construction and any excessive, that is, beyond acceptable levels, deviations should be noted, recorded, and reported for research as to its root cause, so that appropriate corrective measures can be taken.

6.4.6.1 Essentially, the alignment measurements for plate edges and structural shapes should be made, after welding, on the following:

1. Shell assemblies, including transverse and longitudinal framing and floors.
2. Longitudinal and transverse bulkhead assemblies.
4. Secondary structures, such as foundation, masts, rudders, tanks, trunks, and so forth.

6.4.6.2 Standard tolerances and acceptable levels for misalignment of various structural members are contained in SSC 273, JSQS–Hull Part, IHI SPAIS (3, 7, 8), or Guide F 1053/F 1053M.

6.4.6.3 The fairness of the plating, frames, beams, stiffeners, etc., should be checked and maintained within acceptable tolerances. Any unfairness found to be permissible should result in a generally fair curve across the plating panel or other structural members.

6.4.7 Weld Inspections—Weld inspections consist of visual surveys, physical measurements, and nondestructive examinations. Weld inspections should be performed no sooner than 24 h after the weld is completed and cool.

6.4.7.1 Weld inspections should be performed in the as-welded condition of the structure, that is, before coating. The weld to be inspected should be clean and all slag should be removed. Simple tools, such as a ruler, throat gage, undercut gage, or a fillet leg gage should be used in measurements to support visual examinations.

6.4.7.2 Tolerance standards and maximum levels of acceptability for welding defects shown as follows are contained, as are all other structural standards, in SSC 273, JSQS–Hull Part, IHI SPAIS (3, 7, 8), American Welding Society references, and classification society documents.

6.4.7.3 Methods, procedures, evaluation, and other requirements for NDE are provided by AWS, SSC–213, ABS (6, 9), and others.

6.4.7.4 Visual inspections and NDE examinations should be directed toward the detection of the following possible weld defects or deficiencies:

1. Errors in weld size per drawings.
2. Lack of fusion (NDE).
3. Undercuts.
4. Deviations from weld contour.
5. Fissures, cracks, or crack-like indications (NDE).
6. Porosity, NDE as well as visually.
7. Failure to wrap around fillet welds.
8. Visible evidence of arc strikes.
9. Sharp or ragged edges.
10. Excessive slag.
11. Slugged welds.
12. Incomplete welds.

6.4.8 NDE—NDEs should be performed according to the building specifications (detailed in the design inspection plan and as contained in the construction inspection program), and
the accompanying field sketches agreed upon by the shipowners, shipyard, and classification society surveyors.

6.4.9 Final Structural Surveys and Tightness Tests—Final structural surveys should be accomplished prior to completion of any unit, module, or the complete erection on the shipway. For all in-process inspections, but specifically for the joint final structural surveys, the preparation of the structure for inspection is very important.

6.4.9.1 During the final structural survey, all the structures should be inspected visually for completeness of all work, including attachments, penetrations, and all permanent access fittings and closures.

6.4.9.2 Tanks, compartments, cofferdams, and void spaces should be tested for tightness to prevent the spreading of flooding, fire, and gases. Tightness checks can be accomplished by means of hose tests, air pressure tests, hydrostatic tests, vacuum box tests, or weld boundary pressure tests. Tests should be carried out in accordance with a compartment testing diagram to be prepared by the shipyard’s engineering department.

6.4.10 Inspection by Classification Societies and Flag State Representatives—These inspections ensure the vessel’s structural integrity and its compliance with the rules and regulations from the standpoint of meeting minimum requirements.

6.4.10.1 Classification societies conduct their own inspections by resident surveyors during the vessel’s construction period. At the end of the construction period, resident surveyors prepare and submit a surveyor report, which is used as one of the inputs for classification society decisions relating to acceptability of the vessel for classification.

6.4.10.2 Flag states also conduct inspections of marine vessels intended to operate under their registration during construction to ensure compliance with the applicable regulations. At the end of the inspection, a file is prepared containing some of the initial plans and design calculations, which also are used in decisions later in the life of the vessel.

6.5 Common Structural Deficiencies:

6.5.1 Many shipyards already have in-house publications for use in identifying most frequently encountered structural deficiencies and recommended corrective measures. Publicly available documents also exist for this purpose. Some of the references that contain common deficiencies, standard tolerances, and standard corrective measures are Guide F 1053/F 1053M, SSC 273, JSQS–Hull Part, IHI SPAIS, Production Standards of the German Shipbuilding Industry, and VIS–530 (3, 4, 5, 7, 8).

6.5.2 Some commonly encountered structural deficiencies are illustrated in Figs. 2–11, which should assist inspectors in identifying them during surveys:

6.5.2.1 Misalignment, Figs. 2 and 3.
6.5.2.2 Excessive gap between members, Fig. 4.
6.5.2.3 Stiffener tilt, Fig. 5.
6.5.2.4 Improper distance between adjacent welds, Figs. 6–8.
6.5.2.5 Weld flaws.
6.5.2.6 Weld undercut.
6.5.2.7 Distortion, Figs. 9 and 10.
6.5.2.8 Deformation of plate, Fig. 11.

6.5.2.9 Cracks, dents, creases, and other damage.

6.6 Recording/Reporting/Evaluation Procedures:

6.6.1 Appropriate forms should be developed or adopted from similar forms used by others for requesting, recording, reporting (corrective action), analyzing, and processing structural inspections, and NDE. Caution should be used as forms developed and used by one shipyard may be different from those used by others, reflecting differences in the quality control organization. These forms should include the following information: record the inspection results, did the condition meet the specification, and, if not, what must be done to correct the situation, including requested assistance from outside bidders.

6.6.2 Dissemination of Inspection Results:

6.6.2.1 Findings from inspection activities, as they relate to specific parts of the ship’s structure, should be recorded on appropriate forms and maintained in the owner’s, ship’s, shipyard’s, or class society’s inspection file. Applicable forms should be distributed to the proper departments in the shipyard, to the owner’s representatives, and to classification society surveyors for review and execution or approval of the recommended corrective action. Each of these is a separate activity, but all in support of the owner.

6.6.2.2 Most important is the feedback of inspection results to the structural designer. By being aware of the deficiencies found and the corrective actions accomplished on the structure,
the designer can analyze the causes and consequences of the deficiency, decide whether the corrective action was sufficient, and determine if the original design should be modified to prevent recurrence of similar deficiencies in follow-on constructions. If such information is proprietary to the owner, the owner should provide such information to the designer.

6.6.2.3 Maintaining brief but clear records of all structural deficiencies and repairs will enable the shipyard to determine the as-built condition of the marine vessel’s structure.

6.7 A thorough review and analysis of all structural inspection reports and deficiency/corrective action records will enable the shipyard to prepare a structural history of the ship’s construction and the condition of its structure as built. This information should be compiled into a complete “Structure Condition Record” for use as a reference basis throughout the ship’s service life. It should record:
6.7.1 All inspected structure found to be within acceptable tolerances. 
6.7.2 The actual accepted tolerances, or deviations from standard, for the structures. 
6.7.3 Structure found to have deviations larger than allowable levels, but jointly accepted by yard, owner, classification society, and flag state inspectors as not requiring corrective action. 
6.7.4 The extent of actual deviations for these structures or structural elements. Structures found to have unacceptable deviations but repaired using standard corrective action procedures. 
6.7.5 Structure found to have unacceptably large deviations for which the original design had to be modified to avoid recurrences of deficiencies. 

7. Preparation of In-Service Inspection Program 
7.1 At the end of a ship’s construction period, the “Design Inspection Plan,” the “Construction Inspection Program,” and the “Structure Condition Record” should be prepared for structural inspections to be performed during the vessel’s operating life. This guide should reconcile the three aforementioned documents and include the following: 
7.1.1 Identification of telltale areas as determined in the “Design Inspection Plan.” 
7.1.2 Any changes to telltale areas due to built-in material deficiencies or accepted fabrication errors during the construction process. 
7.1.3 Other significant areas for inspection, not due to design allowance, but due solely to material or fabrication errors, or both, during construction. 
7.1.4 Prepare an inspection checklist based on the preceding considerations identifying all structures to be subjected to in-service inspections. The inspection checklist should include: 
7.1.4.1 Inspection frequencies. 
7.1.4.2 Methods and procedures for inspections. 
7.1.4.3 Tools and equipment to be used. 
7.1.4.4 Responsibilities for performance of inspections, that is, whether to be conducted by the owner’s representatives
while vessel is in service, by a shipyard crew while afloat, or by the yard crew during drydocking, and so forth.

7.1.4.5 Cargo to be carried.
7.1.4.6 Marine vessel’s service.
7.1.4.7 History of prior in-service inspections.

7.2 In-Service Inspections:

7.2.1 General:

7.2.1.1 The condition of the ship’s structure should be kept under constant surveillance by situational and periodical inspections throughout its operating life in accordance with an in-service inspection program. This plan is prepared during final stages of the construction period and should take into account necessary flag state- and classification-society required inspection and surveys.

7.2.1.2 Structural inspections conducted between those required by the flag state or classification society must be based on decisions by the owner, and it is his responsibility to provide trained personnel to conduct the inspections while the vessel is in service. Some periodic inspections may be performed by the crew, but some would require preparations or training beyond normally expected crew capabilities.

7.2.1.3 The in-service inspection program prepared during the construction period should include, among other things, the identified telltale areas for which the owner’s representatives should perform interim inspections. The program also should have flagged those structures that are considered significant due to design features or fabrication history, that is, built-in material/fabrication/workmanship variations.

7.2.1.4 The in-service inspection program should be updated during the vessel’s life to reflect the extent of coatings breakdown, service in which the vessel is operated, and how the structure has withstood that service. As problems develop during the life of the vessel, standard repair procedures for recurring problems should be developed and entered into the inspection program for the specific details. In subsequent inspections, these repairs should be inspected to verify that they have solved the preexisting problem. Repair procedures should be developed with classification society and flag state concurrence.

7.2.2 Owner’s Representatives Inspection:

7.2.2.1 In general, owner’s representatives will have some opportunity to inspect the structure while at sea. These inspections may reveal deterioration or damage to parts of the structure that may be repaired by the crew, riding maintenance persons, or if more detailed inspection and repair is needed, possibly in a shipyard. In some cases, parts of the ship’s structure may be uninspectable while at sea because the structure may be inaccessible due to existence of fuel, water, cargo, insulation, and so forth, in the spaces to be inspected. In this case, the owner should plan ahead for yard inspections.

7.2.2.2 Owner representatives’ inspections, when possible, can accomplish the following:

(1) Detect and repair minor damage and deterioration.
(2) Obtain an early warning of major structural problems.
(3) Keep corrosion control systems under surveillance.
(4) Identify areas for detailed surveys and plan and budget for shipyard availability.

(5) By doing all of the preceding, reduce overall survey and repair costs.

7.2.2.3 Some of the typical structural flaws that the owner’s representatives can detect are:

(1) Scale formation on plates and shapes.
(2) Pitting.
(3) Localized wastage.
(4) Resultant loss of thickness.
(5) Wastage of zinc anodes in tanks, if used.
(6) Poor condition of coatings.
(7) Buckling in structural members.
(8) Fractures, cracks.
(9) Other obvious damage, such as dents, creases, and so forth.

7.2.2.4 In addition to main structural elements, inspections also should cover miscellaneous structures, such as handrails, ladders, platforms, valve reach rods, and so forth.

7.2.2.5 Enhanced surveys of main structural members inspected by the owner’s representatives with the concurrence of the class society, to the extent possible, should include deck plating, underdeck girders and longitudinals, side shell plating and framing, transverse and longitudinal bulkheads with their stiffeners, and stringer platforms, if any, as well as other areas of concern as determined by IMO, IACS, or the particular class society or flag state.

7.2.2.6 Figs. 11-22 show some typical structural deficiencies, such as, fractures, buckling, and deterioration, that can be detected by owner representative’s inspections. These sketches are applicable to the design of a tanker. Similar sketches should be developed for the specific ship to be inspected and included in the in-service inspection program. The Tanker Structure Cooperative Form Guidance Manuals (10) are especially good sources for graphical representations.

7.2.3 Periodic Inspection by Classification Societies and Port and Flag State Representatives—These bodies conduct inspections of the marine vessel’s structure in accordance with well-established procedures requirements. It is the owner’s
responsibility to ensure the vessel is properly maintained. Sole reliance on these bodies’ minimum periodic inspections is not judicial. Typical procedures and frequencies are described in detail in the classification society rules as applicable to vessels of varying types and by flag state requirements.

7.2.4 Repair and Conversion Inspections:

7.2.4.1 The procedures to be followed in performing structural inspection for and during major repairs and overhaul availabilities, essentially, are combinations of construction and in-service inspection procedures. The repairs to any structure due to damage or deterioration should follow established repair procedures contained in the in-service inspection program. Whenever the damage is so extensive that removal of the existing structure and renewal with new materials is required, the construction inspection program requirements should be observed.

7.2.4.2 When alterations are to be made to the existing structure as necessitated by a conversion design, the areas to be modified should be structurally inspected in accordance with
in-service inspection requirements. The newly constructed parts or additional structures should be inspected in accordance with new construction requirements.

7.2.4.3 Special attention should be given to the continuity and compatibility of structures and materials for major structural renewals and for structural modifications or additions, or both.

7.2.5 Maintaining and Updating the Structure Condition Record:

7.2.5.1 The Structure Condition Record (SCR) prepared at the end of the construction period should be referred to before initiating periodic in-service inspection activities, even if the specific requirements from it have already been incorporated into an In-Service Inspection Program. The SCR should have descriptive background information to enable structural inspectors to understand better the reasons for special inspection requirements for the specific parts of the structure.

7.2.5.2 The SCR should be kept current by modifying the existing data or by adding new data, as applicable, from the results of any in-service inspections or any corrective measures, or both, taken on the basis thereof.

8. Keywords

8.1 crack; damage; defect; dent; details; distribution; examination; failure; flaws; fracture; inspection; nondestructive; structures; welds
FIG. 20 Typical Bottom Shell Loss Patterns
Reproduced by special permission from "Large Oil Tanker Structural Survey Experience" by Exxon Corporation Tanker Department, June 1982.
FIG. 21 Center Girder Cracking
Reproduced by special permission from "Large Oil Tanker Structural Survey Experience" by Exxon Corporation Tanker Department, June 1982.
REFERENCES

(1) Resolution A.272(VIII) Recommendations on Safe Access to and Working in Large Tanks, and Recommendations on Safe Access to and Working in Large Cargo Holds of Bulk Carriers, International Maritime Organization (IMO), 1973 (Amended by Resolution A330(IX)).

(2) NVIC (Navigation and Vessel Inspection Circular) 10–82, United States Coast Guard, Washington, DC, 18 May 1982.


1. Scope

1.1 This specification provides the requirements for design, construction, performance, and testing of solid state bargraph-type indicating meters.

1.2 The solid state bargraph meters covered by this specification are intended for use in shipboard applications of electrical measurement. This specification covers the requirements and quality assurance provisions for solid state, panel-type (edgewise), and rectangular switchboard-type instruments, which use light-emitting diodes (LEDs) for bargraph indication and optional digital displays.

1.3 This specification’s requirements may be invoked for specialized measurement applications where another quantity, for example, position, weight, concentration of a trace element in an atmosphere sample, and so forth, is converted to electrical energy for display and measurement. Special dial markings shall be specified for such cases.

1.4 The values stated in metric units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
B 117 Practice for Operating Salt Spray (Fog) Apparatus
D 3951 Practice for Commercial Packaging
F 1166 Practice for Human Engineering Design for Marine Systems, Equipment and Facilities

2.2 Federal Specifications:
TT–E–529 Enamel, Alkyd, Semigloss, Low VOC Content

2.3 Federal Standards:
H28 Screw Thread Standards for Federal Services

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 accuracy, \( n \)—the accuracy is a number that defines the limit of errors expressed as a percentage of full-scale value.

3.1.2 center-zero meter, \( n \)—meter with display mode characterized by a sequentially illuminated string of LEDs starting at the center scale zero position and extending in either direction from zero, proportional to the polarity and magnitude of the input signal.

3.1.3 dual bargraph display, \( n \)—two completely independent bargraph displays included in a single enclosure.

3.1.4 end-scale value, \( n \)—the value of the actuating electrical quantity that corresponds to end scale indication. When zero is not at the end or at the electrical center of the scale, the higher value is used. See Table 1.

3.1.5 end-zero meter, \( n \)—meter with display mode characterized by a sequentially illuminated string of LEDs starting from a zero point, normally at the left for switchboard-style meters or horizontally installed edgewise meters, or the bottom of vertically installed edgewise meters, that extends in the direction of full-scale value.

3.1.6 full-scale value, \( n \)—full-scale value is the largest value of the actuating electrical quantity, which can be indicated on the scale. For instruments with zero between the ends of the scale, the full-scale value is the arithmetic sum of the values of the actuating electrical quantity corresponding to the two ends of the scale.

3.1.7 response time, \( n \)—the response time is the time required for the indicating means to display a new value after a step change has occurred in the measured quantity to a new constant value.

3.1.8 scale division, \( n \)—a scale division is the increment between the centers of two consecutive scale marks. The number of scale marks is one more than the number of scale divisions. For example, 10 scale divisions require 11 scale marks.

3.1.8.1 linear scale divisions, \( n \)—linear scale divisions are scale divisions that are spaced an equal distance apart and of the same value, for example, scale divisions spaced 5 \text{A} apart on a 100–A meter.

3.1.8.2 nonlinear scale divisions, \( n \)—nonlinear scale divisions are scale divisions of the same value spaced an unequal distance apart.
TABLE 1 End-Scale Values

<table>
<thead>
<tr>
<th>Range</th>
<th>End-Scale Values (for Ratings)</th>
<th>End-Scale Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-150</td>
<td>0, 150</td>
<td>150</td>
</tr>
<tr>
<td>50-0-150</td>
<td>50, 150</td>
<td>150</td>
</tr>
<tr>
<td>150-0-150</td>
<td>150, 150</td>
<td>150</td>
</tr>
<tr>
<td>90-140</td>
<td>90, 140</td>
<td>140</td>
</tr>
</tbody>
</table>

3.1.9 scale length, \( n \)—the scale length is the length of the path described by the pattern of the LEDs in moving from one end of the scale to the other. For multiple scale meters, the longest scale shall be used to determine the scale length.

3.1.10 scale visibility, \( n \)—scale visibility is the maximum horizontal or vertical viewing angle measured from a line normal to the scale from which all scale marks and arcs, but not necessarily all markings, may be seen.

4. Classification

4.1 Classification—Bargraph meters covered in this specification shall be classified by type and style as specified in 4.2-4.3.

4.2 Type—The type designation defines the physical configuration of the meter and the scale.

4.2.1 Rectangular/switchboard-type meters present angular displays from 90 to 270° scale for the measured parameter(s). Fig. 1 provides typical dimensional and mounting data for rectangular/switchboard-type meters.

4.2.2 Edgewise/panel-type meters present linear displays for measured parameters. Fig. 2 provides typical dimensional and mounting data for edgewise type meters.

4.2.2.1 Orientation of Meter—For edgewise/panel-type meters, the scale marking shall be specified either for a vertical or horizontal mounting condition.

4.3 Style—The style designation defines the meters display attributes as follows:

4.3.1 Bargraph Display—The bargraph display shall consist of light-emitting diode (LED) elements that illuminate to produce a bar image proportional to the input signal. The display designation defines whether the meter has single or dual bargraph displays.

4.3.2 Digital Display—The digital display designation defines the number of digits in the digital display as follows:

4.3.2.1 3-digit display.
4.3.2.2 3½-digit display.
4.3.2.3 4-digit display.
4.3.2.4 4½-digit display
4.3.2.5 No digital display.

5. Ordering Information

5.1 Purchase orders or inquiries for bargraph meters of this specification shall specify the following:
5.1.1 Title, date, and year of this specification.
5.1.2 Quantity.
5.1.3 Type and for edgewise meter, the orientation (see 4.2).
5.1.4 Style of display (single or dual, digital display) (see 4.3).
5.1.5 Window type (plastic or shatterproof glass) (see 7.5).
5.1.6 Dial colors (see 7.9.1.1).
5.1.7 Range(s) (see 7.9.2).
5.1.8 Power supply voltage (see 8.1.1).
5.1.9 Signal input (analog or digital) (see 8.1.2).
5.1.10 Color(s) of bargraph display (see 8.2.2).
5.1.11 Optional features available:

5.1.11.1 Anti-glare windows (see 7.5.1).
5.1.11.2 Splashproof or spraytight window (see 7.5.2).
5.1.11.3 Internal illumination (see 7.6).
5.1.11.4 External accessories (see 7.8).
5.1.11.5 Alarm set points (see 8.1.4).
5.1.11.6 Digital display:
5.1.11.7 Nonstandard range values (see 8.2.4).
5.1.11.8 Dot matrix display types (see 8.2.4).
5.1.11.9 Intensity control (see 8.2.5).
5.1.12 Certification requirements (See 10).
5.1.13 Packaging requirements.
5.1.14 Testing requirements (include only if tests other than the production tests required by this specification are to be performed).

6. Materials and Manufacture

6.1 Materials—All materials used in the construction of these bargraph meters shall be of a quality suitable for the purpose intended and shall conform to the requirements of this specification.

6.1.1 Metals—Metals and the treatment of metals shall be corrosion-resistant.

6.1.2 Plastics—Plastic, when used, shall be suitable thermoplastic or thermosetting material so molded as to produce a dense solid structure, uniform in texture, finish, and mechanical properties.

6.1.3 Glass—Glass used for the meter window shall be the shatterproof type.

6.1.4 Gaskets—Material used in gaskets shall not cause corrosion of metal parts with which they come in contact.

6.2 Manufacture:

6.2.1 Finishes:

6.2.1.1 External Finishes—The portion of the meter case exposed to view from the front of the panel or switchboard shall have a black semigloss finish. No nickel or bright trimmings shall be used. The external finish may be epoxy-coated, electro-coated, or painted in accordance with TT–E–529. Metal cases shall be rendered resistant to corrosion prior to the application of the final finish.

6.2.1.2 Internal Finishes—Internal finishes shall be of a material that shall not melt, crack, chip, blister, or scale as a result of the tests specified herein.

6.3 Threaded Parts—Threaded parts shall be in accordance with FED-STD-H28. Where practical, threads shall be in conformity with the coarse-thread series. The fine-thread series shall be used only for applications that might show a definite advantage through their use. Where a special diameter pitch combination is required, the thread shall be of American National Form and of any pitch between 16 and 36 which is used in the fine-thread series.

6.3.1 Locking of Screw-Thread Assemblies—Screw-thread assemblies shall not loosen as a result of the tests specified herein. When practicable, split-type lockwashers or equivalent means shall be provided under all nuts.
### DIMENSIONAL CHARACTERISTICS FOR RECTANGULAR/SWITCHBOARD-TYPE METERS

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F₁</th>
<th>F₂</th>
<th>F₃</th>
<th>G</th>
<th>H</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>112 mm (4.43 in)</td>
<td>17.4 mm (0.69 in)</td>
<td>135 mm (5.31 in)</td>
<td>—</td>
<td>101 mm (3.98 in)</td>
<td>—</td>
<td>—</td>
<td>43 mm (1.69 in)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>101.6 mm (4.0 in)</td>
</tr>
<tr>
<td>216 mm (8.75 in)</td>
<td>26.2 mm (1.03 in)</td>
<td>135 mm (5.31 in)</td>
<td>—</td>
<td>101 mm (3.98 in)</td>
<td>—</td>
<td>—</td>
<td>43 mm (1.69 in)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>101.6 mm (4.0 in)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F₁</th>
<th>F₂</th>
<th>F₃</th>
<th>G</th>
<th>H</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>123 mm (4.84 in)</td>
<td>19 mm (0.75 in)</td>
<td>142 mm (5.6 in)</td>
<td>50.8 mm (2.0 in)</td>
<td>—</td>
<td>43 mm (1.69 in)</td>
<td>43 mm (1.69 in)</td>
<td>—</td>
<td>114 mm (4.49 in)</td>
<td>54 mm (2.13 in)</td>
<td>109 mm (4.3 in)</td>
<td>—</td>
</tr>
<tr>
<td>118 mm (4.63 in)</td>
<td>22.3 mm (0.88 in)</td>
<td>142 mm (5.6 in)</td>
<td>50.8 mm (2.0 in)</td>
<td>—</td>
<td>43 mm (1.69 in)</td>
<td>43 mm (1.69 in)</td>
<td>—</td>
<td>95 mm (3.75 in)</td>
<td>57 mm (2.25 in)</td>
<td>86 mm (3.38 in)</td>
<td>—</td>
</tr>
<tr>
<td>118 mm (4.63 in)</td>
<td>22.3 mm (0.88 in)</td>
<td>142 mm (5.6 in)</td>
<td>50.8 mm (2.0 in)</td>
<td>—</td>
<td>43 mm (1.69 in)</td>
<td>43 mm (1.69 in)</td>
<td>—</td>
<td>114 mm (4.49 in)</td>
<td>54 mm (2.13 in)</td>
<td>108 mm (4.26 in)</td>
<td>—</td>
</tr>
<tr>
<td>181 mm (7.13 in)</td>
<td>22.3 mm (0.88 in)</td>
<td>217 mm (8.55 in)</td>
<td>40.6 mm (1.6 in)</td>
<td>—</td>
<td>63.5 mm (2.5 in)</td>
<td>83 mm (3.26 in)</td>
<td>—</td>
<td>172 mm (6.78 in)</td>
<td>47 mm (1.84 in)</td>
<td>137 mm (5.38 in)</td>
<td>—</td>
</tr>
</tbody>
</table>

**NOTES:** All dimensions are in millimeters (inches are in parenthesis and are nominal unless otherwise specified).

FIG. 1 Rectangular/Switchboard/Type Meters
### FIG. 2 Dimensional Characteristics of Edgewise Meters

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>133.35 mm (5.25 in)</td>
<td>131.95 mm (5.20 in)</td>
<td>-</td>
<td>14.61 mm (0.58 in)</td>
<td>36.53 mm (1.44 in)</td>
<td>110.74 mm (4.36 in)</td>
<td>36.58 mm (1.44 in)</td>
<td>22.99 mm (0.91 in)</td>
</tr>
<tr>
<td></td>
<td>146.55 mm (5.77 in)</td>
<td>140.0 mm (5.5 in)</td>
<td>116.8 mm (4.6 in)</td>
<td>15.5 mm (0.61 in)</td>
<td>31.0 mm (1.22 in)</td>
<td>118.1 mm (4.65 in)</td>
<td>26.9 mm (1.06 in)</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>152.4 mm (6.0 in)</td>
<td>171.0 mm (6.73 in)</td>
<td>144.1 mm (5.675 in)</td>
<td>13.7 mm (0.54 in)</td>
<td>54.86 mm (2.16 in)</td>
<td>144.78 mm (5.7 in)</td>
<td>45.0 mm (1.77 in)</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>152.4 mm (6.0 in)</td>
<td>217.2 mm (8.55)</td>
<td>136.5 mm (5.375 in)</td>
<td>20.3 mm (.80 in)</td>
<td>44.2 mm (1.75 in)</td>
<td>172.2 mm (6.78 in)</td>
<td>46.7 mm (1.84 in)</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>170.2 mm (6.7 in)</td>
<td>154.0 mm (6.06 in)</td>
<td>116.8 mm (4.6 in)</td>
<td>15.5 mm (0.610 in)</td>
<td>38.86 mm (1.53 in)</td>
<td>139.1 mm (5.475 in)</td>
<td>31.5 mm (1.24 in)</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>177.8 mm (7.0 in)</td>
<td>184.2 mm (7.25 in)</td>
<td>138.9 mm (5.47 in)</td>
<td>12.7 mm (0.5 in)</td>
<td>63.5 mm (2.50 in)</td>
<td>139.7 mm (5.5 in)</td>
<td>47.6 mm (1.875 in)</td>
<td>41.3 mm (1.625 in)</td>
</tr>
<tr>
<td></td>
<td>241.3 mm (9.5 in)</td>
<td>114.3 mm (4.5 in)</td>
<td>182.9 mm (7.2 in)</td>
<td>20.3 mm (0.8 in)</td>
<td>45.72 mm (1.8 in)</td>
<td>184.2 mm (7.25 in)</td>
<td>38.1 mm (1.5 in)</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>254.0 mm (10.0 in)</td>
<td>269.2 mm (10.6 in)</td>
<td>215.1 mm (8.47 in)</td>
<td>12.7 mm (0.5 in)</td>
<td>91.95 mm (3.62 in)</td>
<td>215.9 mm (8.5 in)</td>
<td>76.2 mm (3.0 in)</td>
<td>63.5 mm (2.5 in)</td>
</tr>
<tr>
<td></td>
<td>285.7 mm (11.25 in)</td>
<td>217.2 mm (8.55)</td>
<td>136.5 mm (5.375 in)</td>
<td>20.8 mm (.820 in)</td>
<td>91.7 mm (3.6 in)</td>
<td>172.2 mm (6.78 in)</td>
<td>46.7 mm (1.84 in)</td>
<td>---</td>
</tr>
</tbody>
</table>

**NOTES:** All dimensions are in millimeters (inches are in parentheses and are nominal unless otherwise specified). For specific drilling information, contact the manufacturer.

**Fig. 2** Dimensional Characteristics of Edgewise Meters
6.4 Sealing—The meter case shall be sealed by means of gaskets, by fusing or soldering metal-to-metal or metal-to-glass, or other means which will enable the meter to withstand the tests specified herein.

7. Design and Construction

7.1 Dimensional Data—Typical physical dimensions for switchboard and edgewise meters are shown in Fig. 1 and Fig. 2.

7.2 Mounting—Bargraph meter shall be front panel mounted to simplify mechanical installation or removal for service, or both. Electrical connections locations shall be designed to facilitate meter removal. Typical mounting dimensions are indicated in Fig. 1 and Fig. 2.

7.2.1 Mounting Hardware—The necessary mounting hardware, such as mounting clips, nuts, washers, bolts, shall be supplied with each meter. The machine screws shall have the same finish as the external finish (see 6.2.1.1).

7.3 Maintainability—The meter shall be constructed so that no special tools are required for insertion or removal of the meter.

7.4 Cases—Cases shall be corrosion resistant. Cases shall be designed and constructed with close-fitting joints to minimize the entrance of dust and moisture (see 6.4).

7.5 Windows—The meter display shall be provided with a window of methyl methacrylate (MMA), polycarbonate (PC), or shatterproof glass. If the window is made MMA or PC, the external surface shall be treated to resist scratching. The window shall be free from detrimental defects that would prevent the display from being easily read or from meeting the luminous distribution and color requirement. Such defects include electrostatic effects, scratches, chips, cracks, or craze.

7.5.1 Anti-Glare Coatings—When anti-glare is specified, windows shall be coated with an anti-glare coating. The coating shall be uniform in quality and condition, clean, smooth, and free from foreign materials. The coating shall show no evidence of flaking, peeling, or blistering. The coating shall not contain blemishes such as discolorations, stains, smears, and streaks. The coating shall show no evidence of a cloudy or hazy appearance.

7.5.1.1 Specular Reflectance—The coating reflectance shall not be greater than 0.6 % for energy incident on the surface at an angle of 0 to 15° inclusive. The reflectance shall be not greater than 1.0 % at an angle of 30°.

7.5.1.2 Light Loss—The coating light loss shall be not greater than 2.0 %.

7.5.2 Splashproof/Spraytight Windows—When specified, splashproof or spraytight windows shall be furnished.

7.6 Internal Illumination—When specified, meters shall be equipped with internal illumination provided by a minimum of two lamps, so placed to illuminate the dial evenly.

7.7 Auxiliary Components—All connections from the shunts and resistors to the input terminals of the meters shall be insulated to prevent shock hazard.

7.8 External Accessories—External shunt, shunt leads, transformers, resistors, and other external accessories shall be furnished when required.

7.9 Meter Scales:

7.9.1 Dial—The dial shall be made of stiff material and shall be supported and secured firmly to the meter.

7.9.1.1 Dial Colors—The meter dial shall have white markings on a black background as standard.

7.9.1.2 Dial Markings—Dial legend markings shall be sharply defined and visible from the front of the case but not distract attention from the scale markings. Unless otherwise specified, the following information shall be marked on the dial or on an attached nameplate.

(a) Manufacturer’s name.

(b) Units of measurement.

(c) The quantity producing end-scale deflection. For end-zero meters, the dial markings shall be FS, indicating full scale, followed by the full-scale value and units of measurement, for example, FS-50 mV. For meters that are not end-zero meters, the dial markings shall be marked ES indicating end scale followed by the end-scale value and units of measurement, for example, ES-50 mV).

7.9.2 Ranges—For end-zero meters, the full-scale ranges shall be as specified. For meters that are not end-zero meters, the center and end-scale ranges shall be specified appropriately.

7.9.3 Scale Divisions—Unless otherwise specified, the value of each scale division shall be one, two, or five of the units measured or any decimal multiple or submultiple of these numbers.

7.9.3.1 Linear Scales—The total number of scale divisions shall be determined by dividing the total range by the smallest increment. For example; a 150-V scale with the smallest increment of 5 V is listed as having 30 scale divisions.

7.9.3.2 Nonlinear Scales—The total number of scale divisions shall be determined by dividing the total range by the smallest increment, although to avoid crowding scale marks, a portion of the scale shall not be marked. For example, a 100-A scale with the smallest increment of 2 A, but with no marks between 0 and 10 A, is listed as having 50 scale divisions.

7.9.4 Scale Visibility—The scale and characters shall be uniform visually in character brightness, legibility, and cleanliness of display with all elements of the meter illuminated. The entire meter scale shall be clearly visible from a distance of 1 m (3 ft) and from a viewing angle of 45° from normal; both vertically and horizontally. The scale visibility shall not deteriorate during the tests specified herein.

7.9.5 Scale Markings—Numerals, letters, and symbols shall be in accordance with Practice F 1166. Scale markings shall be as specified herein.

7.9.5.1 The orientation of numerals shall be tangential or erect for 90° scales, erect for 180 and 270° scaleplates, and erect for edgewise scales.

7.9.5.2 The sequence of scale divisions and numerals through the linear portion of the scale plate shall be uniform.

7.9.5.3 The scales shall begin and end with a numbered mark, including 0, when applicable.

7.9.5.4 There shall be not greater than five minor scale divisions between an intermediate or major scale division nor greater than three intermediate scale divisions between a major scale division.

7.9.5.5 The numbered markings shall be spaced uniformly and shall be expressed in the same units of measurement as
those of the end-scale marking. One, two, and five or decimal multiples thereof, shall be used when possible.

7.9.5.6 Scale division markings shall occupy not greater than 20 % of the space between a scale division mark and an adjacent mark.

8. Requirements

8.1 Electrical Requirements:

8.1.1 Power Supply Voltage—The meters shall operate from a voltage as specified as follows. A means of reverse voltage protection shall be provided:

\[
\begin{align*}
&5 \pm 0.25 \text{ V direct current (Vdc)} \\
&28 \pm 1.0 \text{ Vdc} \\
&115 \pm 8.0 \text{ V alternating current (Vac)}
\end{align*}
\]

8.1.2 Signal Input—The meters shall accept a digital or analog signal as specified.

8.1.3 Insulation Resistance—The insulation resistance shall be not less than 2 M\(\Omega\) between the external terminals and the meter case.

8.1.4 Alarm Set Points—When specified, the meter shall be furnished with adjustable visible set points with form-C relay contact outputs for control of external devices such as remote alarms. The hysteresis of set points shall be not greater than 1.0 % of full scale.

8.1.4.1 Setting—Set points shall be programmed from the front of the meter. Set points should be set to a point on the bargraph as standard and use of the digital display for setting exact numerical values is an option.

8.2 Displays:

8.2.1 Color Coding—The LED color coding shall conform to Practice F 1166.

8.2.2 Bargraph Display—The bargraph display shall consist of segmented LED displays of the colors specified, which illuminate to produce a bar image equal to the corresponding scale value of the input. LED display color selection includes red, green, amber or use of tricolor LED display as an option.

8.2.3 Power-On Indication—The zero LED shall be continuously illuminated to serve as a “power on” and as a “zero reference” even in the absence of a signal input.

8.2.4 Digital Display—When specified, the meter shall include a red LED digital display that shall display continuously a specified range of values. The standard digital display shall match the bargraph display. An optional feature of different range values for the digital and bargraph displays shall be available when specified. The standard nominal character height shall be 4.88 mm (0.192 in.) for edgewise types with 2.4 mm (0.095 in.) as an option. The standard nominal character height shall be 10.5 mm (0.41 in.) for switchboard-type meters. The display type shall be seven segment as standard with dot matrix as an option.

8.2.5 Intensity Control—When specified, dimming controls shall be provided to maintain appropriate brightness, legibility, and operator dark adaptation level. These controls shall apply to all LED displays and, when used, dial illumination. The display luminance value shall vary in direct proportion to ambient lighting, and the dial illumination in inverse proportion.

8.2.6 Adjustments—The meter shall contain provisions to adjust the zero-offset and full-scale range. The adjustment devices shall be accessible from the rear of the meter when connected to the input signal and power supply sources.

8.2.7 Set Point Visual Indication—Visual indication of the set point locations shall be shown on the bargraph display by illuminating that LED segment corresponding to the set value when the input signal is lower than the set point value. When the input signal is greater than the set point value, the LED segment corresponding with the set point value is off. When the signal level is one LED segment greater or lower than the set point value, the LED corresponding to the set point value will flash once a second (1 Hz). When the signal level and the set point value are the same, the LED corresponding to the location will flash twice a second (2 Hz).

8.3 Performance Requirements:

8.3.1 Zero Adjustment—The meter shall include provision for zero adjustment by automatic or manual means. Manual means for zero adjustments shall provide for a minimum excursion of ±1 % of full scale about scale zero. The means shall be designed such that scale zero does not change as a result of any of the tests specified herein.

8.3.2 Span Adjustment—The meter shall include provision for span adjustment that provides for a full-scale adjustment above and below full scale of not less than 1.0 % of the rated full scale. The span adjuster shall be designed to prevent it from shaking loose and changing adjustment when subject to tests specified herein.

8.3.3 Accuracy:

8.3.3.1 Bargraph Display—The required accuracy of the meter bargraph display shall be established using the following equation:

\[
\text{Bargraph display accuracy} = \frac{100}{\text{number of LED elements}} - 1
\]

8.3.3.2 Digital Display Accuracy—The error of the digital display shall be not greater than 1.0 % for 3- and 3½-digit displays and shall be not greater than 0.1 % for displays with 4- and 4½-digit displays.

8.3.4 Response Time—The response time of the meter shall be not greater than 2 s for a zero to full-scale step input or full scale to zero step input signal.

8.3.5 Display Illuminance:

8.3.5.1 Axial Illuminance—The bargraph segment shall have a minimum illuminance of 60 mcd (0.6 mfc) at a distance of 200 mm (3.8 in.).

8.3.5.2 Illuminance Variation—The illuminance variation of the bargraph segments and the digital displays shall be not greater than 2.4 to 1.

8.3.6 Chromaticity—The chromaticity for LEDs shall be as follows:

8.3.6.1 Red shall be standard high efficiency with a dominant wavelength of 626 ± 2 nm.

8.3.6.2 Green shall be standard high efficiency with a dominant wavelength of 574 ± 2 nm.

8.3.6.3 Amber shall be standard high efficiency with a dominant wavelength of 585 ± 2 nm.

8.3.7 Overload—The meter shall be able to withstand a momentary overload of 200 % of full scale. The meter shall withstand a sustained overload of 20 % of full scale. During an overload, the digital display shall indicate the full-scale value
and all LED display elements shall illuminate except the most significant LED element shall flash. The meter shall meet the accuracy requirements of 8.3.3.

8.4 Environmental Requirements:

8.4.1 Temperature—The meter shall operate in an ambient temperature range from 0 to +65°C, and shall withstand, without damage, a nonoperating (storage) temperature range of −55 to +85°C. The temperature error shall be not greater than the accuracy requirements of 8.3.3.

8.4.2 Vibration—The meters shall show no evidence of breakage, permanent deformation, or loosening of parts and shall retain their serviceability. The meter shall meet the accuracy requirements of 8.3.3.

8.4.3 Salt Fog—The meter shall show no evidence of salt penetration into the meter encasement nor evidence of corrosive effects, peeling, flaking, or color change in material.

8.4.4 Temperature-Humidity Cycling—The meter shall show no evidence of deterioration of parts or materials, loosening of finishes, physical distortion, corrosion of metals, moisture entrapment, or separation of bonded surfaces. The meter shall meet the accuracy requirements of 8.3.3.

9. Conformance and Production Tests

9.1 Conformance testing of a random sample may be requested by the purchaser to verify that selected performance characteristics specified in this standard have been incorporated in the meter design and have been maintained in the production bargraph meters supplied. These tests would not normally be performed unless specifically required. Production tests are routine tests performed on production units, or samples thereof, to ensure that basic requirements are met.

9.2 Reference Conditions—Reference conditions for testing meter performance shall be as follows:

9.2.1 Temperature: 23 ± 2°C.

9.2.2 Relative humidity: 40 to 60%.

9.2.3 Atmospheric pressure: 575- to 800-mm mercury.

9.2.4 Position: on vertical panel.

9.2.5 External magnetic field: of the earth’s field only.

9.2.6 Waveform (ac meter only): sinusoidal.

9.2.7 Warm-up time: 30 min.

9.2.8 Frequency (for ac meters other than frequency meters): rated ±3%.

9.2.9 Voltage (for meters other than volunteers): rated value.

9.3 Zero Adjust—Meters shall be set to zero with use of the zero adjuster at the completion of each test.

9.4 Number of Scale Readings—Scale reading shall be taken at approximately six equidistant points on the scale including the end-scale points.

9.5 Calibration—A calibration inspection shall be conducted when specified in the individual test. It consists of applying known values of excitation to the meter, with not less than five equally spaced intervals over the full range of the meter and recording the correspondingly displayed values.

9.6 Conformance Tests:

9.6.1 Accuracy—The accuracy shall be determined for the bargraph and digital displays under reference conditions (see 9.1) as follows:

9.6.1.1 Apply excitation to illuminate the exact end-scale LED mark and record the value of excitation.

9.6.1.2 Within 15 min, reduce the value of excitation to illuminate LEDs of not less than five other approximately equidistant scale marks including the zero mark. Measure and record the value of excitation at each scale mark.

9.6.1.3 The difference between the reference and measured conditions shall be calculated, in percentage of full scale, for each measured point. The accuracy of the meter shall be verified by using the greatest difference, in percentage, that was calculated.

9.6.2 Response Time—A photodetector with known response characteristics, having adequate sensitivity and resolution to respond to one element of the display, shall be positioned at the 80% element of the meter display. The photodetector output shall be monitored with a storage oscilloscope or other suitable means. A signal input not less than 80% of the meter range shall be applied to the meter input in less than 10 ms and held constant. This signal shall also be used to trigger the oscilloscope. Response time required for the display element at 80% to illuminate shall be determined.

9.6.3 Insulation Resistance—The insulation resistance of the meter shall be determined by applying a test voltage (V₁) between the external terminals and the meter case, through a 1000-Ω resistor. The type of current applied (ac or dc) is dependent upon the terminal’s normally applied excitation. The level of V₁ for circuits whose normally applied level is less than 50 V shall be 250 V. The level of V₁ for circuits whose normal excitation is 50 V and higher shall be 10 times the normal excitation or 1000 Vdc (707 V rms), whichever is less. The current flowing through the terminals to ground is determined using the following:

\[ E_M = \frac{V_M}{R_M} \]

where:

- \( E_M \) = Voltage drop across resistor;
- \( R_M \) = Resistance, 1000 Ω; and
- \( I_M \) = Current through terminals to ground.

The insulation resistance can be determined using \( I_M \) in the following equation:

\[ \frac{V_T}{I_M} - 1000 \Omega = IR_M \]

where:

- \( IR_M \) = Insulation resistance of meter.

9.6.4 Display Illuminance—Illuminance shall be measured with instrumentation having a response that is within 2% of the International Commission on Illumination (CIE) photopic curve over the specified color region.

9.6.4.1 Axial Luminance—The illuminance shall be measured with no ambient lighting, with all segments of the meter’s display illuminated. All readings shall be taken to and at a distance of 200 mm from the plane of the front surface of the display elements, centered on the horizontal and vertical axes of the bargraph display. The luminance measurements shall be taken with a calibrated photometer and recorded.

9.6.4.2 Luminance Variation—Measure the illuminance of each segment on the center of its display surface in accordance with 9.6.4.1. Record the highest and the lowest readings...
obtained. The luminance variation \( (D_L) \) shall be determined using these readings in the following equation:

\[
D_L = \frac{\text{highest reading}}{\text{lowest reading}}
\]

9.6.5 Chromaticity—The bargraph meter chromaticity shall be determined by using one of the following three methods:

9.6.5.1 Method I—Spectrophotometer—Chromaticity shall be determined using a spectrophotometer, flat slab material of the same density and thickness of the shaped filter, and necessary calibration filters.

9.6.5.2 Method II—Spectroradiometric—Chromaticity shall be determined using a spectroradiometer, a completely illuminated meter, calibrated lamps of specific color temperature, and necessary calibration filters.

9.6.5.3 Method III—Visual Comparator—Chromaticity shall be determined by a color comparator, necessary high and low limit plastic or glass filters of known chromaticity, and calibrated light sources of specific color temperature.

9.6.6 Overload:

9.6.6.1 Momentary Overload—The voltage/current circuits of ac and dc meters shall be subjected to an application of 200 % of the rated full-scale value for 2 min. After 30 min at reference conditions (see 9.1) following the test, the meter shall be reset to zero and the change in indication shall be determined. The accuracy requirements of 8.3.3 shall be verified.

9.6.6.2 Sustained Overload—The meter shall be subjected for 8 h to an application of voltage/current 20 % greater than full-scale value. After 30 min at reference conditions (see 9.1) following the test, the meter shall be reset to zero and the change in indication shall be determined. The accuracy requirements of 8.3.3 shall be verified.

9.6.7 Temperature—The meter shall be tested, without alignment or adjustment, throughout the following temperature cycle:

9.6.7.1 Hold ambient temperature at 0 ± 2°C for not less than 24 h.

9.6.7.2 Increase ambient temperature in steps of 10° each, at 30 min/step, until 65 ± 2°C is reached, and hold at that temperature for not less than 4 h.

9.6.7.3 Reduce ambient temperature in steps of 10° each, at 30 min/step, until 25 ± 2°C is reached, and hold at that temperature for not less than 4 h.

9.6.7.4 At each temperature plateau (0, 65, and 25°C), a calibration cycle (see 9.5) shall be made. The temperature error is calculated as the change in indication caused by a temperature change of ±10°C from the three temperature points (0, 65, and 25°C).

9.6.8 Vibration—The meter shall be subjected to a simple harmonic motion in the X plane having an amplitude of 0.23 to 0.25 mm (0.46– to 0.50-mm total excursion), the frequency being varied uniformly between 500 and 2500 cycles/min for 20 min. The entire frequency range, from 500 to 2500 cycles/min and return to 500 cycles/min, shall be transversed at a rate of change of frequency of 200 ± 25 cycles/min. During the test, an input equal to 80 ± 5 % of the meter span shall be applied to the meter. After the test, the meter shall be examined visually and the accuracy verified in accordance with 9.6.1. Repeat for the Y and Z planes.

9.6.9 Salt Fog—The meter shall be tested in accordance with Practice B 117. The exposure time shall be 48 h followed by a 48-h drying period. The meter shall be examined visually after the test.

9.6.10 Temperature/Humidity Cycling—The meter shall be tested as specified in the following paragraphs. No adjustments during the test shall be made, other than the accessible controls employed for operation of the equipment.

9.6.10.1 Conditioning—To establish a reference condition, the meter shall be dried at a temperature not less than 40°C or greater than 50°C for not less than 2 h.

9.6.10.2 Calibration Cycles—Following the conditioning, a calibration cycle shall be performed as specified in 9.5 to indicate the satisfactory performance of the meter. This calibration cycle shall be conducted at 25 ± 5°C and 50 ± 5 % relative humidity. In addition, axial luminance shall be measured as specified in 9.6.4.1, except that only five segments of the display shall be measured. Throughout this test, the same five segments shall be monitored.

9.6.10.3 Temperature Cycling—Meters shall then be subjected to five 24-h cycles of temperature variation consisting of not less than 16 h at 65 ± 5°C and approximately 8 h at 25 ± 5°C. The relative humidity shall be maintained above a minimum of 95 % during the steady-state conditions. The transitions between temperatures shall be accomplished within 8-h period so that the time at the high temperature is not less than 16 h. Each transition shall be not greater than 1½ h if the meter remains in the chamber. If a two-chamber method is used, both chambers shall be stabilized at their appropriate settings before transferring the test units. The relative humidity need not be controlled during the transition periods. The chamber(s) used shall be proven able to maintain uniform temperature and humidity throughout the chamber.

9.6.10.4 Measurements—During the second cycle the measurements specified in 9.5 shall be taken at 65 ± 5°C with the meter remaining in the chamber. The meter shall be energized for as brief a period as required to complete the measurements. A warm-up period shall be permitted in which previous tests indicate a definite period is required for the meter to attain thermal stability. After the five complete cycles, the measurements specified in 9.5 shall be performed at 25 ± 5°C with the meter remaining in the chamber.

9.6.10.5 Conditioning—Upon completion of the tests, the meter shall remain inoperative for not less than 12 or greater than 24 h at a temperature at 25 ± 5°C and 50 ± 5 % relative humidity.

9.6.10.6 Humidity Cycling—The meter shall be operated continuously with an input equivalent to 80 ± 5 % of the meter span in an ambient temperature of 50 ± 5°C for a period of 8 h. The relative humidity shall be increased from 50 ± 5 % to 95 ± 5 % during the final 2 h.

9.6.10.7 Measurements—The meter’s calibration shall be checked and recorded (see 9.5) at 2-h intervals, for a total of four checks. At each check, the same five input values shall be used.

9.6.11 Workmanship—Meters shall be manufactured in such a manner as to be uniform in quality. The interiors of the meters shall be free from metal filings, grease or oil, foreign material,
dust, or other loose particles that will affect the performance, serviceability, or appearance of the meter.

9.7 Production Tests:
9.7.1 Visual, Mechanical, and Workmanship Examination—Meters shall be examined visually and mechanically to verify that materials, design, construction, physical dimensions, workmanship, and markings are as specified in this specification.

10. Certification Requirements
10.1 When specified in the purchase order or contract, a producer’s or supplier’s certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

11. Marking Requirements
11.1 Meter markings—Each meter shall be provided with an identification plate. Plastic identification plates shall be used when attaching to other than a flat surface. Unless otherwise specified, the following shall be marked on the identification plates:

11.1.1 Manufacturer’s name.
11.1.2 Manufacturer’s type or model number.
11.1.3 Manufacturer’s serial number.
11.1.4 Year of manufacture.
11.1.5 Country of origin.

12. Packaging Requirements
12.1 Product shall be packaged, boxed, crated, or wrapped to provide suitable protection during shipment and storage.
12.2 Preservation of meters shall be in accordance with Practice D 3951.

13. Quality Assurance
13.1 The manufacturer of the solid state bargraph meters shall maintain the quality of the meters that are designed, tested, and marked in accordance with this specification. At no time shall a meter be sold with this specification designation that does not meet the requirements herein.

14. Keywords
14.1 analog display; bargraph meter; digital display; edge-wise meter; electrical measurement; light-emitting diode; switchboard meter; solid state meter

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are applicable to DoD procurements and shall apply only when specified by the purchaser in the contract or purchase order.

S1. Referenced Documents
S1.1 Military Specifications:
MIL–S–901 Shock Tests, H.I. (High-Impact), Requirements for Shipboard Machinery, Equipment, and Systems

S1.2 Military Standards:
MIL–STD–167–1 Mechanical Vibrations of Shipboard Equipment (Type I–Environmental and Type II–Internally Excited)
MIL–STD–461 Electromagnetic Emission and Susceptibility Requirements for the Control of Electromanetic Interference

S2. Dial Colors
S2.1 Dial Colors—For U.S. Navy applications, the dial color combination shall have black on a white background as standard (see 7.9.5). This color scheme optimizes visibility of meter in conditions of low ambient lighting, such as red-out locations.

S3. Vibration Tests
S3.1 Vibration Tests—The meter shall be tested in accordance with MIL–STD–167–1, Type I. During the test, an input equal to 80 ± 5 % of the meter span shall be applied to the meter.
S3.2 Examination After Vibration Tests—The meters shall show no evidence of breakage, permanent deformation, or loosening of parts and shall retain their serviceability. The meter shall meet the accuracy requirements of 8.3.3.

S4. Shock Tests
S4.1 Shock Tests—The meter shall be tested in accordance with MIL–S–901, Grade A, Class I, Type A. During the test, an input equal to 80 ± 5 % of the meter span shall be applied to the meter.
S4.2 Examination After Shock Tests—The meter shall show no evidence of screws, windows, or other parts being loose, cracked, or excessively damaged. The meter shall meet the accuracy requirements of 8.3.3.

S5. Electromagnetic Interference (EMI) Requirements
S5.1 The meter shall meet the following requirements of MIL–STD–461 for surface ships and submarines: CE 101, CE 102, CS 101, CS 114, CS 116, RE 101, RE 102, RS 101, and
RS 103. The applicable electric field levels for requirements
RS 103 shall be as follows:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>E-field level</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 kHz – 2 MHz</td>
<td>10 V/m</td>
</tr>
<tr>
<td>2 MHz – 30 MHz</td>
<td>50 V/m</td>
</tr>
<tr>
<td>30 MHz – 18 GHz</td>
<td>10 V/m</td>
</tr>
</tbody>
</table>

S5.2 **Electromagnetic Interference Tests**—The meter shall
be tested in accordance with the applicable procedures in
MIL–STD–462.

S6. **Terminals**

S6.1 The meters shall be furnished with terminal connectors
in accordance with MIL-C-24308. The connector pin assign-
ments shall conform to S6.1.1 and S6.1.2

S6.1.1 **Digital Input**—The meter shall include two connec-
tors, which shall be as follows:

S6.1.1.1 M24308/4–1
S6.1.1.2 M24308/4–3.

S6.1.2 **Analog Input**—The meter shall include a connector
conforming to M24308/24–43 complete with jack screw hard-
ware, M24308/26–1. The connector pins shall be as follows:

S6.1.2.1 Input signal (+).
S6.1.2.2 Input signal (−).
S6.1.2.3 LED test input signal, if applicable.
S6.1.2.4 LED test input return, if applicable.
S6.1.2.5 Power supply.
S6.1.2.6 Power supply.

This standard is issued under the fixed designation F 1756; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides an overview and guide for the selection and implementation by shipowners and operators of a Fleet Management System (FMS) network of computer services in a client/server architecture (see Fig. 1). The FMS is based upon a wide area enterprise network consisting of an unspecified number of Shipboard Information Technology Platforms (SITPs) and one or more shoreside Land-Based Information Technology Platforms (LITPs), which provides management services for the shipping enterprise. The FMS can be understood as a computer system comprised of one or more LITPs and one or more SITPs. It can be characterized as mission critical 24 × 365 (24 h/day, 365 days/year).

1.2 The SITP (see Fig. 1) provides a set of software services, including:

1.2.1 Communications Services, to communicate between vessels and with shore via multiple wireless communication technologies;

1.2.2 Data Acquisition Services, providing access to shipboard system data as required for use by other systems and management purposes; and,

1.2.3 Executive Services, providing software process administration and control.

1.2.4 In total, the SITP provides the capability for multiple shipboard computer systems to share data with each other and to communicate with shore-based management or other vessels or both.

1.3 The SITP is understood to consist of integrated hardware, software, a data repository, and standardized procedures, which provide the ability to send, receive, process, transfer, and store data or messages in digital form in a common mode from shipboard systems or administrative utilities or both, and from designated sources outside the network, for example, systems accessed through wireless communication services, such as satellite, VHF, HF, and so forth. Shipboard systems include navigational, machinery control and monitoring, cargo control, communications, and so forth. The SITP also will provide the capability for the remote administration and maintenance of associated computer systems aboard the vessel.

1.4 The SITP requires an underlying hardware and network infrastructure, including a shipboard computer local area network (LAN), file servers, workstations, wireless communications transceivers, cabling, other electronic and optical devices, video display units, keyboards, and so forth.

1.5 The SITP also requires underlying system software providing network operating system (NOS) services, DBMS services, and other system software.

1.6 There also is a layer of shipboard application systems, which are designed to capitalize on the FMS infrastructure to share data with other shipboard systems and management ashore. Those systems also would be able to capitalize on the remote management capabilities of the FMS.

1.7 The LITP is an asset that can exchange operating and administrative data from individual ships and maintain a DBMS to support fleet management and other maritime applications. The LITP will support data repositories, file servers, workstations or personal computers (PCs), and a communication hub providing connectivity to distributed satellite services, VHF (very high frequency), HF/MF (high frequency/medium frequency), and land lines. The DBMS makes possible the development of knowledge-based “decision aids” by providing the ability to retrieve, process, and analyze operational data.

1.8 This guide does not purport to address all the requirements for a SITP, which forms a path for data for direct control of the operation or condition of the vessel or the vessel subsystems.

1.9 In all cases, it shall be possible for all units of navigation equipment resident on the Navigation Equipment Bus to operate and display essential operating data independently of the FMS.

1.10 In all cases, it shall be possible for all units resident on the Control, Monitoring, and Alarm Bus to operate and display essential operating data independently of the FMS.

1.11 In all cases, it shall be possible for all units resident on the Communications Bus to operate and display essential operating data independently of the FMS.

1.12 Values shown in this guide are in SI units.
1.13 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
E 919 Specification for Software Documentation for a Computerized System
E 1013 Terminology Relating to Computerized Systems
F 1166 Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities
F 1757 Guide for Digital Communication Protocols for Computerized Systems

2.2 ANSI Standards:
X3.172 Dictionary for Information Systems
X3.172a Dictionary for Information Systems (Computer Security Glossary)

2.3 IEEE Standards:
IEEE 45 Recommended Practice for Electrical Installations on Shipboard

2.4 IEC Documents:
IEC 50 International Electrotechnical Vocabulary (IEV)
IEC 92–504 Electrical Installations in Ships; Special Features—Control and Instrumentation
IEC 533 Electromagnetic Compatibility of Electrical and Electronic Installations in Ships and of Mobile and Fixed Offshore Units
IEC 945 Maritime Navigation and Radiocommunication Equipment and Systems
IEC 1162 Maritime Navigation and Radiocommunication Equipment and Systems—Digital Interfaces
IEC 1209 Integrated Bridge Systems (IBS) for Ships

2.5 NMEA (National Marine Electronics Association) Standards:
NMEA 0183 Standard for Interfacing Electronic Marine Navigational Devices

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5 Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854–1331.
6 Available from the National Marine Electronics Association (NMEA) Seven Riggs Ave., Severna Park, MD 21146.
3. Terminology

3.1 Definitions: Definitions of terms in this guide and described below are in accordance with Terminology E 1013 and ANSI X3.172 and X3.172a.

3.1.1 application program, n—a computer program that performs a task related to the process being controlled rather than to the functioning of the computer itself.

3.1.2 application programming interface (API), n—an API is a set of rules for linking various software components of a network.

3.1.3 automatic information system (AIS), n—automatic distribution of a ship’s voyage information to all interested parties, that is, other ships, port state, owner, and so forth.

3.1.4 baseband network, n—only one transmission can be on the network at any given time.

3.1.5 black box test, n—black box tests are based on the design specification and do not require a knowledge of the internal program structure.

3.1.6 certification, n—the process of formal approval, by an authority empowered to do so, of arrangements or systems for the reception, storage, or transmission of data and intelligence relative to the management, operation, or control of vessels.

3.1.7 client server database engine, n—a commercial data base management system serving as a repository for all critical ship operating and configuration information.

3.1.8 computer program, n—a set of ordered instructions that specify operations in a form suitable for execution by a digital computer.

3.1.9 computer system, n—a functional unit, consisting of one or more computers and associated software, that uses common storage for all or part of a program and also for all or part of the data necessary for the execution of the program.

3.1.10 configuration manager, n—utilities that determine the data to be collected, the processing and storage rules, the standard software functions that facilitate the interfaces between systems and the FMS process servers and other configuration parameters.

3.1.11 data replicator/message processor, n—a software module that is responsible for receiving, decoding, and storing communications and transmissions received from ships. This module also prepares data for transmission to a ship through the land-based communications hub.

3.1.12 document management system, n—an application that allows procedures manuals to be stored and accessed electronically on shipboard and to be updated electronically.

3.1.13 electronic mail system, n—a messaging and file transfer system for both ship and shore.

3.1.14 fault tolerance, n—the built-in capacity of a system to provide continued correct execution in the presence of a limited number of hardware of software faults.

3.1.15 fleet management system (FMS), n—a system of computer services in a client/server architecture, based on a wide area enterprise network consisting of an unspecified number of SITPs and the LITP. The FMS can be understood as an integrated system of software, hardware, communication protocols to be stored and accessed in the FMS database in a standard format.

3.1.16 independent, n—independent as applied to two systems means that either system will operate with the failure of any part of the other system excluding the source of power.

3.1.17 interface, n—the interface attribute describes the methods and rules governing interaction between different entities.

3.1.18 integration tests, n—tests performed during the hardware/software integration process before computer system validation to verify compatibility.

3.1.19 land-based communications hub, n—a land-based system that provides uniform access to multiple maritime satellite services, as well as access to public telephone networks, e-mail, and the internet.

3.1.20 local area network (LAN), n—a network that connects computer systems resident in a small area. For purposes of this guide, the SITP is considered a shipboard LAN with access to similar shoreside and shipboard units through radio and satellite telecommunication services.

3.1.21 MSAT—satellite communications service covering North America.

3.1.22 multitasking, n—the capability to handle more than one task at a time.

3.1.23 NAVTEX, n—a system for the broadcast and automatic reception of maritime safety information by means of a narrow-band direct-printing telegraphy.

3.1.24 network interface unit (NIU), n—the network interface units (NIUs) provide for connection and message translation to enable data streams from systems, both hardware and software, which may use various standard and proprietary communication protocols to be stored and accessed in the FMS database in a standard format.

3.1.25 ship information technology platform (computing), n—an integrated system of software, hardware, communication links, and standardized procedures that provide the ability to collect, process, and store information in digital form.

3.1.26 ship earth station, n—a mobile earth station for maritime service located aboard a ship. Typically, a small lightweight terminal with omnidirectional antenna with interfaces for a personal computer or any other data terminal equipment for message generation and display, for example, Inmarsat C, or a steerable antenna mounted on a stabilized platform, for example, Inmarsat A and B and M.

3.1.27 single failure criterion, n—a criterion applied to a system such that it is capable of performing its safety task in the presence of any single failure.

3.1.28 software, n—programs, procedures, rules, and associated documentation pertaining to the operation of a computer system.

3.1.29 software cycle—the software cycle typically includes a requirements phase, a design phase, an implementation phase, a test phase, an installation and checkout phase, and an operation and maintenance phase.

3.1.30 validation—the test and evaluation of the integrated computer system, hardware and software, to ensure compliance with the functional, performance, and interface requirements.

3.1.31 verification, n—the process to determine if the product of each phase of the digital computer system development process satisfies the requirements set by the previous phase.
3.1.32 voyage data recorder (VDR), n—a store of information, in a secure and retrievable form, concerning the position, movement, physical status, command, and control of a vessel over the period leading up to a marine casualty.

3.1.33 white box test, n—white box tests require a knowledge of the internal program structure and are based on the internal design specification.

3.1.34 workstation, n—a computer and associated visual display unit (monitor) configured as an I/O unit to perform certain tasks.

4. Significance and Use

4.1 Competent information management is essential for safe and productive operation and regulatory compliance. A short list of the functions affected includes decision aids for navigation, communications, ship handling, machinery control, cargo operations, maintenance and repair, personnel records, and environmental protection.

4.2 The shipbuilding and shipping industries have identified a need to develop comprehensive standards and guides for implementing computer-based shipboard data management systems.

4.3 The FMS may include single or multiple SITPs and single or multiple LITPs and provides the means to integrate shipboard and shore-based computer systems with multivendor connectivity, distributed processing, and electronic data interchange between noncompatible networks, computers, workstations, and peripherals and maintain databases, which promote safety of life at sea, protection of the environment, and operational efficiencies throughout the life cycle of the vessel/fleet. The FMS may incorporate satellite gateways to coastal communication hubs providing access to land-based networks, such as telephone lines, facsimile, e-mail, and expanded satellite services through land earth stations.

4.4 The SITP can be configured to provide the ship’s control center with access to local control centers, such as for cargo operations, which may be located on the main deck.

4.5 This guide has provisions relevant to all components of the FMS platform including the ship earth station, interface devices for subsystems and administrative systems connected to or forming part of the network, communication services, and certain land-based facilities under the direct control of the ship’s management.

4.6 It is the intent of this guide to provide guidelines for the design and implementation of open client/server architecture for computer and communication networks for shipboard and shore-based applications.

4.7 This guide is intended to assist vessel owners, designers, shipyards, equipment suppliers, and computer service providers in the development of contract technical specifications, which detail the services to be supported, performance required, and criteria for acceptance for specific FMS installations.

5. FMS Architecture

5.1 Network Design—There is an underlying computer network to support the FMS. The functions of the FMS enable a communication network that provides for the exchange of information between nodes or devices capable of transmitting or receiving information in the form of electronic or optical signals. The process is enabled by communication protocols, which define the rules that must be implemented in the hardware and software. The text of this guide is predicated on a network architecture conforming to the Open Systems Interconnection Reference Model (OSI/RM). See Guide F 1757.

5.2 Network Management:

5.2.1 The FMS is based upon a wide area network (WAN) consisting of a number of LANs, which are dispersed geographically over large areas and are linked through wireless communications by bridges and gateway devices. The group responsible for managing the FMS will normally be located in the principal shoreside office. The primary task of the network management system is to oversee and report on the operation of the network, which may comprise products from many different vendors.

5.2.2 Security—A security function should be provided that is responsible for the following:

5.2.2.1 Data confidentiality;
5.2.2.2 Data integrity;
5.2.2.3 Data authentication; and,
5.2.2.4 Access control.

5.3 Database Model—Database maintenance and availability are key features of the FMS. Each SITP and the LITP will maintain separate databases. Each FMS site will incorporate a database management system, including replication capability, as part of each SITP and LITP installation.

6. Shipboard Information Technology Platform (SITP) Connectivity

6.1 A key objective of the SITP is to facilitate sharing of data among shipboard systems (see Fig. 2). The shipboard systems, which are candidates for connection to an SITP include, but are not limited to, the following:

6.1.1 Shipboard Operating Systems—Shipboard operating systems are active systems and may acquire information from sensors or databases and exercise control internally or transmit data for administrative purposes or for application in knowledge-based decision aid systems.

6.1.1.1 Integrated Bridge System—This system comprises the integrated bridge system bus, the navigation equipment bus, and the control, monitoring, and alarm bus.

6.1.1.2 Integrated Bridge System Bus—The integrated bridge system bus provides connectivity for the navigation equipment bus and the control, monitoring, and alarm bus and is a controlled gateway to the administrative network.

6.1.1.3 Navigation Equipment Bus—The navigation equipment bus provides systemwide connectivity for any or all of the following or any additional units associated with the navigation of the vessel: gyro compass/autopilot; global positioning system (GPS); dead reckoning (DR) navigation system; speed and distance indicator (Doppler log); sonic depth finder; electronic chart system (including, but not limited to, ECDIS); rate of turn indicator (ROTI); radar/ARPA (automatic radar plotting aids); radio direction finder; and voyage data recorder (VDR).

6.1.1.4 Control, Monitoring, and Alarm Bus—The control, monitoring, and alarm bus provides systemwide connectivity for any or all of the following or any additional units associated...
Shipboard Operations Administrative Network:

Integrated Bridge System Bus

- Ballast Control
- Mach. Control
- Liquid Cargo
- Fire Control

Trim & Stab.
Interior Comm.
Reefer Controls
HVAC Controls

Navigation Equipment Bus

- Gyro/Autopilot
- Global Pos. Sys.
- Radar/ARPA
- Depth Finder

- DR Position
- Speed & Dist.
- ECDIS
- Rate of Turn

Control, Monitoring & Alarm Bus

Integrated Bridge System (IBS)

FIG. 2 SITP Data Flow (Typical)
directly with control of the vessel: machinery control, monitoring, and alarm; liquid cargo control; inert gas control; ballast control; fire detection and alarm; loading (trim and stability; hull stress); internal communications; WT door and fire door controls; controls for refrigerated cargo; and HVAC controls.

6.1.2 Communications Bus—The communications bus provides connectivity for any or all of the following or any additional units providing communication facilities on board the vessel: Inmarsat A, B, M; Inmarsat C; VHF radiotelephone; MF/HF SSB radiotelephone; cellular; and GMDSS (Global Maritime Distress Safety System—see Appendix X3).

6.1.3 Administration System:

6.1.3.1 Ship-to-Shore Communications:

Electronic mail and file transfer, Connection to local telephone systems, and Sailing instructions (weather routing).

6.1.3.2 Cargo Planning:

Stability and trim, Container ordering, Cargo manifests, Custody transfer procedures and records, and International Maritime Dangerous Goods Code.

6.1.3.3 Fuel Management—Speed/Distance/Consumption:

Fuel rate, Running inventory, Fuel quality records, Bunkering checklist, Bunker planning—grades and quantities, and Cargo heating.

6.1.3.4 Inspections, Maintenance, and Repair:

Inspection schedules, Maintenance and repair (M and R) schedules and records, and Spare parts inventory control (use, ordered, received, and cost).

6.1.3.5 Quality Management:

ISM Code compliance, Quality procedures and records (ISO 9000), and Auditing.

6.1.3.6 Personnel and Safety Management:

Employment records management—payroll, Training and certification, Hazard communication (benzene, asbestos), Respiratory protection, and Occupational health monitoring.

6.1.3.7 Ship’s Documents:


6.1.3.8 Reports:

Automatic information system (AIS) and Voyage data recorder (VDR).

7. Shipboard Information and Technology Platform (SITP)

7.1 The SITP consists of the software and hardware required to support a distributed computing network based on the client/server model. In general, the SITP will be optimized to respond to a single LITP. For cases in which the SITP will respond to multiple shoreside platforms, a hierarchy should be defined. The SITP consists of layers of computer services and underlying layers of system services, including a network operating system and a database management system.

7.1.1 Computing Model—Client/server computing is expected to be the computing model for the SITP. Client/server is a joint operation in which specific computers perform specific tasks. Server tasks generally involve file sharing, database management, communications management, and so forth. Client tasks, on the other hand, are generally active and are defined by the application.

7.1.1.1 Server(s):

(a) Comprises software that is resident on an intelligent machine (a computer);
(b) Is a provider of services. The services may include database services (DBMS), communication services, and processes;
(c) Is a shared resource. One server can serve several clients;
(d) Is transparent to the user. Clients and servers communicate by a messaging interface; and,
(e) Is normally a dedicated PC.

7.1.1.2 The client(s) is normally software that is resident on a PC or work station.

7.1.1.3 Quality—Design, development, modification, replication, and installation should be subject to a documented quality plan. At a minimum, the areas of responsibility, performance, and acceptance criteria should be addressed in the quality plan.

7.1.1.4 The design and testing of the computer services should ensure that:

(a) The implementation satisfies the applicable requirements, which may also include statutory and classification requirements;
(b) Design documentation will show that specification requirements can be traced through all levels;
(c) Module interfaces and dependencies are clearly defined and identified;
(d) Estimates of memory capacity, central processor unit, and bandwidth are reliable and can support hardware selection;
(e) Test procedures are defined and carried out in parallel with the design process; and,
(f) Documentation is subject to formal review.

7.1.2 Required Underlying System Services:

7.1.2.1 Network Operating System—A network operating system supports the following services that should be transparent to the user:

(a) Initialization of the system services;
(b) Enables applications throughout the network;
(c) Provides for multiple user access to programs and database and file services;
(d) File and print services—remote access, read, write, download, and upload;
(e) Gateways to independent networks—the ability to access a remote system; and,
(f) Network management.

7.1.2.2 Security Management—Security management provides an integrated platform-wide, including network operating system and compliant applications, security system that includes:
(a) Discretionary access control (DAC) in which the users may protect their own objects;
(b) Mandatory access control (MAC) in which users may read or write objects for which they have clearance. Users may read objects at the same or lower class and write objects at the same or higher class;
(c) Isolation of the security kernel from noncritical systems;
(d) User authentication/identification;
(e) Audit and log of security-related transactions—log-ins, read or write operations on objects, and log-outs;
(f) System testing;
(g) Users’ guide;
(h) System manual; and
(j) System documentation.

7.1.2.3 Encryption—Radio communications between SITPs and LITPs are exposed to electronic monitoring, and messages transmitted in clear text will be exposed to eavesdropping and intrusion. Data encryption is the most effective protection against such intrusions and should be available for security-sensitive communications. The encryption protocol should provide for multiple algorithms and the assignment of separate algorithms for different types of data. A critical element of the encryption program is the control of data encyphering and data decyphering keys, a key management system. This system is responsible for key origination, application, recording, assignment, and deletion.

7.1.2.4 Virus protection—Includes programmed virus scanning software and floppy disk control.

7.1.2.5 Miscellaneous—Includes automatic checking and reporting of memory errors and automatic reset and reboot after power interruption.

7.1.3 Database Management System:
7.1.3.1 The database management system supports a data repository that provides for storage of data in digital form and manages:
(a) Data acquisition and storage;
(b) Data replication on demand, scheduled or event driven;
(c) Integration of information at multiple remote sites;
(d) Open database connectivity;
(e) Query language;
(f) Concurrency/multiple users; and,
(g) Referential integrity.

7.1.3.2 Database Security—The DMBS should incorporate protection against improper access, improper modification of data (ensure data integrity), and improper denial of access. It should provide for:
(a) Operational Integrity—This addresses the serialization and isolation properties of transactions. Serialization means that the concurrent run of a set of transactions will give identical results as a sequential run of the same set of transactions.

(b) Logical Integrity of Data—Allowed range.
(c) Accountability and Auditing—Record of all read or write access to data.
(d) Privacy—Control of employment, medical records, and so forth.
(e) Delimitation—Control of information transfer between programs.

7.2 SITP Services

7.2.1 The SITP services, as shown in Fig. 1, are required to provide overall command and control of the SITP. The executive has overall responsibility to monitor the SITP and control the distributed processes that operate as platform services. The SITP executive itself is a series of services each of which are responsible for specific tasks. The SITP provides a layer of insulation and control between high- and low-level processes. It uses a set of structured APIs and internal communication channels for message exchange.

7.2.2 Executive Services—The following sections describe the services provided by the SITP executive. These services are each responsible for the orderly registration, control, audit, and monitoring of SITP compliant software processes on the server and supported workstations for their specific function.

7.2.2.1 Process Management—Process control refers to starting, staging, pausing, resuming, and stopping. An SITP process may be an SITP internal process, network operating system process, or an SITP compliant application. The process management interfaces with the SITP compliant process through the SITP APIs and with the process management database. Each physical computer within the SITP will have a process management function. All SITP processes are registered in the SITP process management database that describes the important attributes of the process. All process information is available to the SITP compliant applications.

7.2.2.2 Health Management—Health management is used to check, on an ongoing basis, the current health of all SITP compliant processes and record that finding in the health management database. This information is available to SITP compliant applications.

7.2.2.3 Performance Management—Performance management is used to observe the efficiency of any particular entity in the system. It is through the SITP performance management facilities that a process can make application-specific data available for monitoring. Furthermore, the data is modeled in such a way as to allow a general purpose monitoring application to display performance data for any participating monitored object.

7.2.2.4 Logging Management—The logging management interfaces with the SITP compliant process through the SITP APIs and with the logging management database. An SITP compliant process, locally or remotely, may send unsolicited events to the logging management database. The logging management directs the logging management database to store the event in the event history.

7.2.2.5 Alarm Management—The alarm management interfaces with the SITP compliant process through the SITP APIs and with the alarm management database. An SITP compliant process, locally or remotely, may send an unsolicited alarm of
a particular alarm type to the alarm management for processing. The alarm management directs the alarm management database to store the alarm in the alarm history.

7.2.2.6 Schedule Management—The SITP schedule management will define a standard API for applications to schedule future running of programs, either as one-time or recurring jobs. A history of requests and execution will be maintained. Compliant applications will have access to this data for display, reporting, audit, or diagnostic purposes. Programs can be scheduled to run based on several criteria, such as time and data, or a range of times. Programs also can be configured to run on a recurring basis. The SITP schedule management also will keep a history of execution.

7.2.2.7 Time Management—The SITP will define a standard API for applications to synchronize with a master clock. This will counter the time drift encountered in computer real-time clocks and allow for the synchronization of time stamps for remote systems. In a shipboard system in which distributed systems execute autonomously, synchronization of events is a critical function. The time management is responsible for maintaining the master clock and providing an API for various SITP services to access that information. To present a uniform reference point, the time management should operate in Z (Zulu) Time and date stamp in an accepted international format and arranged to display world local times on demand.

7.2.2.8 Localization Management—The SITP localization management interfaces with the SITP compliant process through the SITP APIs and with the localization management database. An SITP compliant process can request localization information, such as language type, collating sequence, date and money formats, system messages, application strings, and any other locale-related information.

7.2.2.9 Debug Management—The SITP debug management interfaces with SITP compliant processes through the client APIs and with the debug management database. An SITP compliant process can send debug data to the debug management for processing. The debug management will record this debug information in the debug management database.

7.2.2.10 Backup Management—The backup management will service client backup requests. It interfaces with SITP compliant processes through the client APIs and with the backup management database. The SITP platform will define a standard API for the backup and restoration of application files and file sets. A history of backup and restore operations for volumes and sets will be retained. Compliant applications will have access to this data for display, reporting, audit, or diagnostic purposes.

7.2.2.11 Test Management—The testing management will intervene between client test requests and targets. It interfaces with the SITP compliant process through the client APIs and with the testing management database. An SITP compliant process can request test execution or test history information.

7.2.2.12 Messaging Management—The SITP messaging management will define a standard API for applications to transport data among all registered entities on the global SITP network. This will allow applications to send and receive arbitrary data to and from any other SITP application. This includes ship to shore, ship to ship, and shore to ship. A hierarchical naming scheme is supported by the messaging management allowing for orderly classification of communication endpoints. The messaging management will use communications facilities as a transport mechanism for interapplication messages. The communication abstraction provided by the messaging management allows for additional transport mechanisms to be used in the future.

7.2.2.13 Replication Management—The SITP replication management is a generalized mechanism that may be used by SITP application providers to build distributed applications that operate within the SITP environment. The services provided by this facility include the following:

(a) Rules-Based Distribution—Configurable distribution of transactions, at the table level, between ship- and shore-based system sites. SITP can be configured to send all, or selected subsets of, information between system sites at flexible intervals. Further, a redistribution feature allows transactions to be forwarded to multiple sites based on system configuration parameters.

(b) Distribution Control Mechanisms—To maintain data integrity, strong control mechanisms are required to serialize, log, and archive all incoming and outgoing transmissions. Disaster recovery mechanisms are required to resend failed transmissions or allow a complete refresh synchronization between system sites. Confirmation of sent and received transmissions must be passed between system sites to ensure data integrity.

(c) Batched Distribution—As sustained real-time connections between system sites can be costly, the platform will support batched groups of transactions to be transmitted in compressed packets during low-cost time windows.

7.2.2.14 Enterprise Management—Several of the services offered by the executive system provide a means of managing various aspects of the SITP system. The enterprise management allows SITP interfaces to be available for use by remote users. The enterprise management would enable a user at a shore site to invoke SITP APIs on a specific ship.

7.2.2.15 Configuration Management—The configuration management handles requests from client processes via API calls. These requests will either request particular configuration settings or a change to a configuration setting. These client processes can be any SITP compliant process. This service is responsible for updating the configuration database as required and notifying other processes affected by the configuration change.

7.2.3 Data Acquisition Services:

7.2.3.1 The SITP data acquisition module is responsible for communicating with the various shipboard control systems or data collection units to acquire data. The SITP data acquisition is responsible for the orderly registration, control, audit, and monitoring of SITP compliant software processes on the server and supported workstations for data acquisition. The SITP data acquisition will provide a framework in which custom interfaces can be developed to a variety of control systems and data acquisition units.

7.2.3.2 Data acquisition from the monitoring and control bus and the navigation equipment bus generally will be read only. A gateway will be interposed between the integrated
bridge system bus and the administrative and communications networks. The gateway will provide the necessary hardware and software to enable dialog between the integrated bridge system and the administrative and communication networks platform and to enforce the one-way communication where required. Data flow on the administrative and communication networks generally is unrestricted except as may be limited by the security mode. Access to the integrated bridge system bus will be regulated as noted.

7.2.4 Communications Services—The communications manager must serve both remote and local users. To avoid connect-time client server blocking, it should provide for asynchronous dialog with the database server that queues client requests, establishes a link, confirms receipt, and satisfies the queries according to priority without blocking either the client or server. The communications manager provides a common systems interface and support for:

7.2.4.1 Multiple wireless communication services, which may include Inmarsat A, B, M and C; MSAT; ARGOS; Orbcamm; and Mobile Datacom.

7.2.4.2 Radio communications include VHF, HF/MF, and cellular.

7.2.4.3 Route diversification, least cost routing, and carrier choice.

7.2.4.4 Message log and cost allocation.

7.2.5 SITP Compliance—SITP compliance is required for software applications to have access to the services of the SITP. APIs will allow SITP compliance for third-party software applications. An SITP compliant software entity will allow for seamless integration into the platform. There will be four levels of compliance based upon the extent of SITP services used:

7.2.5.1 Level 1:
- Process management,
- Logging management,
- Messaging management, and
- Replication management.

7.2.5.2 Level 2—Includes Level 1 plus the following:
- Alarm management,
- Time management, and
- Configuration management.

7.2.5.3 Level 3—Includes Level 2 plus the following:
- Debug management,
- Backup management,
- Test management, and
- Enterprise management.

7.2.5.4 Level 4—Includes Level 3 plus the following:
- Health management,
- Performance management,
- Schedule management, and
- Localization management.

7.3 Application Programming Interfaces—APIs will be required for third-party applications to use SITP services.

7.3.1 Overview of APIs—The term “application programming interface” (API) is defined as a software tool kit that can be used as a building block that facilitates connections primarily between applications and other constituent network software, but that also can provide linkages for other elements of the network (see Fig. 3). The function of the network operating system is to control shared resources and establish transactions among applications. In multivendor networks without commonality, APIs provide the required link.

8. Land-Based Information Technology Platform (LITP)

8.1 The LITP is the control and communication center of FMS. It provides the infrastructure, software, and hardware, necessary to provide computing and communication services for the management of a wide area network (WAN) of SITPs and any auxiliary shoreside installations. The design profile generally will replicate that of the SITPs it manages, expanded, and optimized as required by the size of the fleet. The underlying service, that is network operating system and database management system, as well as the LITP services, provide the same functions as corresponding services of the SITP described in 7.1.2 and 7.2 except as follows:

8.1.1 Data Acquisition Services—Typically for the LITP, data acquisition from control systems will not be required.

8.1.2 Data Management—The LITP data management function will include acquiring, processing, and warehousing operating data from the various SITPs under its direction. It also may acquire data from any associated shoreside version or from other sources. It will oversee the flow of data to SITPs or LITPs.

8.1.3 Communications Manager—The communications manager will support a communications hub with access to land lines that may include telephone, telefax, e-mail, cellular, and land earth stations.

8.1.4 Configuration Manager—The configuration manager for the LITP responds to requests to reconfigure elements of the WAN, that is, the SITPs and subsidiary shoreside platforms, as well as to its local network.

9. System Hardware

9.1 The selection of system hardware for both the SITP and the LITP must consider a number of factors that are dependent on the nature and the criticality of the applications supported by the FMS. Guidance to assist the designers in the selection of hardware is provided in Appendix X4.

10. Fault Tolerance

10.1 The level of fault tolerance necessary for each FMS installation should be determined as a function of the criticality
of the applications supported by the system. A description of varying levels of fault tolerance is provided in Appendix X5.

11. Communications Bus

11.1 The communications hub provides the physical interface between the communications software and the various transceivers may include, but are not be limited to, the following:

   11.1.1 Satellite Communications:
   11.1.1.1 Circuit-Switched Mode—Inmarsat A, Inmarsat B, Inmarsat M, and MSAT.
   11.1.1.2 Store and Forward Mode—Inmarsat C and Orbi-comm.

   11.1.2 Radio Communications:
   11.1.2.1 Medium and Long Range—MF (300 kHz to 3 Mhz); HF (3 to 30 MHz); emergency communication (500 kHz); weather fax; and radio telex.
   11.1.2.2 Short Range—VHF (30 Mhz to 300 mhz) and cellular.

   11.1.3 GMDSS—See Appendix X3.

12. Demonstration and Validation

12.1 General—Evidence of a satisfactory degree of reliability in the design, manufacture, and installation of the equipment and systems comprising the FMS is to be demonstrated. In general, this demonstration consists of series of certifications, verifications, validations, tests, and trials.

12.2 Test Philosophy—Testing shall be of hierarchical nature, moving from the equipment unit level through testing at the integrated system level to final user testing in the installed environment.

12.3 The system hardware will be tested to ensure that no part of the system can be overstressed as by voltage transients during operation or testing, that components are electrically rated compatible with other design constraints to allow for part parameter variations and transient conditions, and a safe margin in operating temperature.

12.4 LAN Software Assessment:

   12.4.1 As used in this guide, software assessment refers to the methodology for verification and validation of the FMS software. Verification focuses on the functional design, whereas validation focuses on whether the system satisfies the requirements. Software is difficult to test. In contrast to hardware, it does not wear out, it does not operate within discrete parameters, and testing is largely qualitative and inferential. In addition, redundancy is not an effective backup.

   12.4.2 Verification and validation of software products should be carried out for individual products and for the integrated system. There will be a defined software demonstration and validation test plan created for each installation, and the SITP and FMS infrastructure will be tested against that plan. In general, software testing shall be formalized at three points in the development.

   12.4.2.1 Unit Tests, of individual modules in isolation to verify logic and interface characteristics. This is accomplished concurrently with software development.

   12.4.2.2 Integration Tests, of the different units to validate interoperability in accordance with design criteria.

12.4.2.3 Acceptance Tests, of the complete system, including all features and elements of the software in a fully configured hardware state without any element of simulation and in a normal operating environment.

12.5 Tests and Trials:

   12.5.1 Unit Tests (Alpha Testing), are white box tests required for testing individual modules and combinations of modules in isolation to verify logic and interface characteristics. They may focus on the lower levels of the protocol and should be started as soon as the software design will permit.

   12.5.2 Integration tests are white box tests, the purpose of which is to bring together the various layers or segments of the software and hardware, including communication links and gateways, and to test them step by step as the integration proceeds.

   12.5.3 End User (Acceptance) Tests—These are tests of the complete system including software and hardware, as well as communication links and gateways. They should be conducted as installed or in simulated environment (mock-up). For the FMS, this will normally include at least one SITP and one LITP. These are black box tests requiring multiple iterations. At a minimum, the following should be included:

       12.5.3.1 Load/Stress Testing—To confirm the system can handle the peak load conditions, internal and external traffic.
       12.5.3.2 Security Testing—To reveal weak spots in the system by repeated attempts to defeat the security controls.
       12.5.3.3 Performance Testing—These tests exercise all of the software applications, communications links, and database management systems.
       12.5.3.4 Hardware Compatibility Testing—To determine the margin of hardware resources, memory, disk space, speed, and so forth, over requirements.
       12.5.3.5 Configuration Testing—To determine how the systems respond to required alternative configurations in hardware or software.

12.6 Operation and Maintenance—This phase will focus on all aspects of system management including:

       12.6.1 System configuration and modification,
       12.6.2 Anomaly identification and resolution,
       12.6.3 Document control (updating),
       12.6.4 Communication interfaces,
       12.6.5 Latencies, and
       12.6.6 Hardware replacement.

13. Human Interface

13.1 In the design of the user interface to the SITPs and the LITP, reference may be to recognized standards.

13.2 Visual Display Unit (VDU):

13.2.1 The size, color, contrast, and density of text and graphics should be read or interpreted easily from the operator position under all operational lighting conditions. Typeface should be an internationally recognized simple, cleartcut design similar to Helvetica medium.

13.2.2 VDU pages should have a standardized format. Information and functional areas should be presented in a consistent manner.

13.2.3 An overview page or pages should be available to explain the paging system.
13.2.4 Each page should have a unique identifying label shown on the screen.

14. Training and Documentation

14.1 General—Regardless of the technical excellence of the FMS software and hardware, operator training is essential to its successful application. The disconnected nature of ship operations serves to emphasize the need for shipboard personnel to be trained in depth on the operation and maintenance of the system.

14.1.1 It is a condition of this guide that formal training in the operation of the FMS is available.

14.1.2 Administrators and users should be trained in and demonstrate their knowledge of step-by-step procedures for operation of the FMS including, to the extent necessary, instructions for associated subsystems, the administrative network functions, ship earth stations, and the land-based communications hub. The program of instruction should include the following at a minimum:

14.1.2.1 Management of local area networks,
14.1.2.2 Management of wide area networks,
14.1.2.3 Client server systems,
14.1.2.4 Network operating systems,
14.1.2.5 All installed hardware,
14.1.2.6 Maintenance and repair,
14.1.2.7 Knowledge of the regulations concerning telecommunications,
14.1.2.8 Administration of the SITP and FMS systems.

14.2 Documentation:

14.2.1 Documentation can be defined as “the aids provided for the understanding of the structure and intended uses of an information system or its components” (ANSI) and system documentation as “the collection of documents that describe the requirements, capabilities, limitations, design, and operation of an information processing system” (ISO). Both definitions are relevant for the purposes of this guide. In addition, the documentation should comply with the provisions of ANSI/IEEE 1063 as a minimum.

14.2.2 User documentation for the SITP may be presented in a tutorial mode and should include detailed instructions for all permitted operations and for such system adjustments or repairs as may be practicable for on board personnel.

14.2.3 Administrator documentation for the FMS should include, in addition to the user documentation, complete reference material necessary to administer the system.

15. Keywords

15.1 communications service; data acquisition service; DBMS (database management system) service; executive services; fleet management system network; land-based information technology platform; network operating system; shipboard information technology platform

APPENDIXES

(Nonmandatory Information)

X1. ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTS</td>
<td>Automated Maritime Telephone Service</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>AOR</td>
<td>Atlantic Ocean Region (E—East, W—West)</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>ARPA</td>
<td>Advance Research Projects Agency</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>BIOS</td>
<td>Basic Input/Output System</td>
</tr>
<tr>
<td>CCITT</td>
<td>Consultative Committee for International Telegraphy and Telephony</td>
</tr>
<tr>
<td>CES</td>
<td>Coast Earth Station</td>
</tr>
<tr>
<td>CISPR</td>
<td>Comité International Special des Peturbations Radioelectrique (International Special Committee on Radio Interference)</td>
</tr>
<tr>
<td>CMIP</td>
<td>Common Management Information Protocol</td>
</tr>
<tr>
<td>CRS</td>
<td>Coast Radio Station</td>
</tr>
<tr>
<td>DMA</td>
<td>Direct Memory Access</td>
</tr>
<tr>
<td>DSC</td>
<td>Digital Selective Calling</td>
</tr>
<tr>
<td>EBCDIC</td>
<td>Extended Binary Coded Decimal Interchange Code</td>
</tr>
<tr>
<td>EGC</td>
<td>Enhanced Group Call</td>
</tr>
<tr>
<td>ECMA</td>
<td>European Computer Manufacturers Association</td>
</tr>
<tr>
<td>EDI</td>
<td>Electronic Data Interchange</td>
</tr>
<tr>
<td>EIA</td>
<td>Electronic Industries Association</td>
</tr>
<tr>
<td>EMI</td>
<td>Electromagnetic Interference</td>
</tr>
<tr>
<td>EPIRB</td>
<td>Emergency Position-Indicating Radio Beacons</td>
</tr>
<tr>
<td>FCC</td>
<td>Federal Communications Commission</td>
</tr>
<tr>
<td>FDDI</td>
<td>Fiber Distributed Data Interface</td>
</tr>
<tr>
<td>FIPS</td>
<td>Federal Information Processing Specification</td>
</tr>
<tr>
<td>FMS</td>
<td>Fleet Management System</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GMDSS</td>
<td>Global Maritime Distress and Safety Systems</td>
</tr>
<tr>
<td>GOSIP</td>
<td>Government OSI Profile</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HF</td>
<td>High Frequency (see Appendix X2)</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>ICMP</td>
<td>Internet Control Message Protocol</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>ISDN</td>
<td>Integrated Services Digital Network</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>ITE</td>
<td>Information Technology Equipment</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunications Union</td>
</tr>
<tr>
<td>IVD</td>
<td>Integrated Voice and Data</td>
</tr>
<tr>
<td>Kbps</td>
<td>Kilo bits per second</td>
</tr>
<tr>
<td>Kbps</td>
<td>Kilo bytes per second</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>LF</td>
<td>Low Frequency (see Appendix X2)</td>
</tr>
<tr>
<td>MAC</td>
<td>Medium Access Control (OSI physical layer)</td>
</tr>
<tr>
<td>MAN</td>
<td>Metropolitan Area Network</td>
</tr>
<tr>
<td>MAP</td>
<td>Manufacturing Automation Protocol</td>
</tr>
<tr>
<td>MAPI</td>
<td>Message Application Programming Interface</td>
</tr>
<tr>
<td>Mbps</td>
<td>Million bits per second</td>
</tr>
<tr>
<td>MBps</td>
<td>Million bytes per second</td>
</tr>
<tr>
<td>MF</td>
<td>Medium Frequency (see Appendix X2)</td>
</tr>
<tr>
<td>MIPS</td>
<td>Million Instructions per Second</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failure</td>
</tr>
<tr>
<td>NBDP</td>
<td>Narrow Band Direct Printing</td>
</tr>
<tr>
<td>NETBIOS</td>
<td>Network Basic Input Output System</td>
</tr>
<tr>
<td>NFS</td>
<td>Network File Server</td>
</tr>
<tr>
<td>NFT</td>
<td>Network File Transfer</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NMEA</td>
<td>National Marine Electronics Association</td>
</tr>
<tr>
<td>OS/2</td>
<td>Operating System/2</td>
</tr>
<tr>
<td>OISRM</td>
<td>Open Systems Interconnection Reference Model</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>POSIX</td>
<td>Operating system developed by IEEE as Standard 1003</td>
</tr>
<tr>
<td>PSDN</td>
<td>Packet Switching Data Network</td>
</tr>
<tr>
<td>PSN</td>
<td>Packet Switching Network</td>
</tr>
<tr>
<td>RAID</td>
<td>Redundant Array of Inexpensive Discs</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RFI</td>
<td>Radio Frequency Interference</td>
</tr>
<tr>
<td>RISC</td>
<td>Reduced Instruction Set Computer</td>
</tr>
<tr>
<td>RMON</td>
<td>Remote Monitoring of Networks</td>
</tr>
<tr>
<td>ROM</td>
<td>Read Only Memory</td>
</tr>
<tr>
<td>RS-232C</td>
<td>An EIA standard 25-pin connector for computer/terminal interface for signal rates up to 20 kbps</td>
</tr>
<tr>
<td>RS-422</td>
<td>An EIA standard 5-pin connector for signal rates up to 20 kbps</td>
</tr>
</tbody>
</table>

## X2. RELATED DOCUMENTS

### X2.1 ISO Standards:

- ISO 9000 Quality Management and Quality Assurance Standards–Guidelines for Selection and Use
- ISO 9001 Quality Systems–Model for Quality Assurance in Design/Development, Production, Installation and Servicing
- ISO/IEC 8802-3 Information Technology–Local and Metropolitan Area Networks–Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications (Ethernet)
- ISO/IEC 9075 Information Technology–Database Languages–SQL
- ISO 8073 Transport Layer Connection-Oriented Services for the OSI Reference Model
- ISO 8602 Transport Layer Connectionless Services for the OSI Reference Model
- ISO 8326/27 Session Layer Connection-Oriented Services for the OSI Reference Model
- ISO 9548 Session Layer Connectionless Services for the ISO Reference Model
- ISO 8822/23 Presentation Layer Connection-Oriented Services for the OSI Reference Model
- ISO 9576 Presentation Layer Connectionless Services for the OSI Reference Model
- ISO 10020/21 ISO Standard for Message Handling Services Based on the CCITT X.400 Standard
- ISO 8571 ISO Definition of the File Transfer, Access and Management (FTAM) Application

## X3. OVERVIEW OF RADIOCOMMUNICATIONS EQUIPMENT REQUIRED FOR GMDSS

### X3.1 See Fig. X3.1 for an overview of radiocommunications equipment required for GMDSS.
X4. SYSTEM HARDWARE

X4.1 Electromagnetic Interference (EMI)—Equipment to be situated in a shipboard open deck environment must be considered as exposed to high levels of radiated and conducted EMI. Because of a large glass area, the enclosed navigating bridge is treated as an open deck area. The sources of EMI can be classed as intentional emitters and nonintentional emitters. Nonintentional emitters are limited by standard to a level of 10V/m radiated EMI under test conditions. Intentional emitters, which include radar, radio, and so forth, generally are not limited as to radiated strength or direction. In addition to fixed emitters, the navigating bridge area routinely is exposed to radiation from mobile emitters, such as, walkie talkies, with levels of EMI potentially hostile to sensitive electronic equipment. See IEC 945 and IEC 533.

X4.2 Physical Layer:

X4.2.1 Topology—The topology of a network is defined by the logical configuration of the nodes and the interconnecting branches.

X4.2.1.1 Star—In practice, the practical execution for both bus and ring topologies is often star shaped with arms radiating from a central hub to each node or station. The wiring within the hub is connected so that logically the system behaves as a bus or ring. This arrangement allows for diagnosing and isolating faulted circuits or equipment without closing down the entire network.

X4.2.1.2 Bus—The bus (see Fig. 1) is the predominate topology found in LANs generally in conjunction with the Ethernet protocol and using STP cabling. The nodes share the bus, and as a result, only one station can broadcast at a time requiring some form of access control, which is provided by the Ethernet protocol. In the simplest form, transmissions from one node can be read at all the other nodes. The effective maximum transmission speed for the standard Ethernet configuration is about 8 Mbps, and this drops rapidly as traffic increases. This speed can be doubled by duplexing. Switched Ethernet provides each device with its own segment so that it has access to 10-Mbps bandwidth without contention.
X4.2.1.3 Ring—The ring network is characteristic of the token ring protocol. Although commonly shown in ring form, the practical execution is a star-shaped assembly which behaves logically like a ring. Arms from a central concentrator, the multistation access unit (MSAU), radiate to each station. Implementation should be in accordance with IEEE 8802.5 at 16 Mbps over STP.

X4.2.2 Cabling—The type of cable to be used will be governed by the length of the cable, the electromagnetic environment, and the bandwidth.

X4.2.2.1 Copper:
(a) Twisted Pair—Available as “Unshielded Twisted Pair”—UTP or as “Shielded Twisted Pair”—STP. UTP is not protected against noise caused by radiated EMI and generally is not suitable for shipboard use for this reason. STP is provided with a shield of copper foil or copper braid to reduce system noise as a result of radiated EMI.
(b) Coax—The cable consists of insulated central conducting solid copper core surrounded by one or more foil or mesh shields separated by insulation. The central conducting core carries the signal and the shield provides the ground. Coax cable is available as thick coax (10Base5 has been applied as the network backbone) or thin coax (10Base2).

X4.2.2.2 Optical Fibers—Optical fibers possess three important advantages over copper conductors:
(a) Immunity to noise from radiated or conducted EMI;
(b) Very high transmission speeds—100 Mbps over paths of up to 2 km for glass fibers. This is the medium of choice for backbone service; and,
(c) Improved security.

Also available with plastic fibers, but with speeds limited to under 10 Mbps and paths of less than 100 m.

X4.3 Servers—The standard configuration for the shipboard local area network will comprise a process server, a communications server, and a database server, which may be allocated to one or more computers. Estimated minimum requirements for the computer(s)/servers are:

X4.3.1 Processor:
X4.3.1.1 Speed—90 mhz,
X4.3.1.2 Two instructions per clock cycle,
X4.3.1.3 45 MFLOPS (floating point operations/second), and
X4.3.1.4 Scalable.

X4.3.2 Memory (RAM), 40-MB ECC (error, checking, correcting, and reporting).

X4.3.3 Storage Devices:
X4.3.3.1 1.05-GB hot swap fast SCSI-2 disk,
X4.3.3.2 3.5-in., 1.44-MG floppy disk drive, and
X4.3.3.3 CD-ROM—internal SCSI-2, quad speed.

X4.3.4 Network Interface Card.

X4.3.5 Color Monitor (Video Display Unit):
X4.3.5.1 15 in., high resolution, integrated 800 × 600, noninterlaced, refresh rate 72 MHz; and,
X4.3.5.2 512-KB standard video memory.

X4.3.6 Graphic Card.

X4.3.7 Multimedia Sound System Support.

While nominally acting as client, workstations may in addition be configured as servers. When configured in this manner, the requirements of X4.3 would apply. The following apply to a stand-alone workstation:

X4.4.1 Processor:
X4.4.1.1 Speed 75 MHz and
X4.4.1.2 Scalable.

X4.4.2 Memory (RAM), 16-MB ECC.

X4.4.3 Storage Devices:
X4.4.3.1 540-MB fast SCSI-2 hard disk;
X4.4.3.2 3.5-in., 1.44-MB floppy disk drive; and
X4.4.3.3 CD-ROM, internal SCSI-2, quad speed.

X4.4.4 Network Interface Card.

X4.4.5 Graphic Card.

X4.4.6 Multimedia Sound Support System.

X4.4.7 Color Monitor, see X4.3.5.

X4.5 Power Sources—The power supply from the ship’s mains may be subject to the variations given in Table X4.1 (see also IEC 92.101):

X4.5.1 Power supply to SITP may be arranged as follows:
X4.5.1.1 From ship’s main or emergency power supply with power conditioner as required to provide the required quality and backed up by a closed transition uninterruptible power supply with a minimum reserve capacity of 15 min.
X4.5.1.2 An on-line uninterruptible power supply with a minimum reserve capacity of 15 min supplied from the ship’s main with closed transition backup.

X4.6 Embedded Programs—Embedded programs should be documented using the following format:

X4.6.1 The procedure’s actual calling name from within the program should be listed along with a one-line description statement for the calling name. The statement’s purpose is to describe clearly the task associated with the procedure’s name.
X4.6.2 A list of input/output parameters, a description statement for each parameter that describes the task associated with the parameter’s name, a statement as to whether the parameter is an input or an output of the procedure, and a range of valid values for each parameter that may be passed into or out of the procedure.
X4.6.3 A list of calling/called procedures, a description statement for each procedure that describes the task associated with the procedure’s name (this statement should be the same as the one describing the procedure’s calling name), a statement as to whether the procedure is called from within the routine or is the caller of the routine, and the name of the module in which the calling/called procedure can be found.

### TABLE X4.1 Power Sources Variations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Permanent</th>
<th>Permanent</th>
<th>Transient</th>
<th>Transient</th>
<th>Recovery Time, s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>+6, +10</td>
<td>±20</td>
<td>±10</td>
<td>±10</td>
<td>1.5</td>
</tr>
<tr>
<td>Frequency</td>
<td>±5</td>
<td>±5</td>
<td>±5</td>
<td>±5</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: Voltage and frequency variations may occur simultaneously.
Total harmonic loading—5 %. Harmonic loading at any single frequency—3 %.
X4.6.4 A synopsis describing the program flow for the procedure. This synopsis should be a detailed, plain language narrative of what the code is doing.

X4.6.5 A revision history for the procedure that includes the data and a description of the change. The description should include the new revision level for the overall program that has resulted from the module modification.

X4.7 Environmental Conditions—The following are to be considered minimum levels. If the equipment is to be part of a system subject to regulatory body approval, then the requirements of the regulatory body, if stricter, will apply.

X4.7.1 Temperature Range, operating: 5 to 40ºC.
X4.7.2 Humidity, operating (5 to 40ºC): 15 to 80 % relative humidity.
X4.7.3 Vibration, operating random: 0.2 g for 5- to 100-Hz survival random: 2 g for 5 to 100 Hz.
X4.7.4 Electromagnetic Compatibility (EMC), to meet CISPR 22 Class B ITE or equivalent.

X5. FAULT TOLERANCE

X5.1 The purpose of fault tolerance is to minimize the impact of hardware or software failures on the network and particularly to prevent the loss of data. The following is a description of several of the methods of backup that may be considered.

X5.2 “Hot Swap” Backup—This allows continuous use while replacing a failed drive.

X5.2.1 Disk Mirroring—This system provides for everything to be written to two disks simultaneously; if the primary disk fails, the standby disk can take over automatically. In this system, both disks are served by a single controller.

X5.2.2 Disk Duplexing—This system provides for everything to be written to two disks simultaneously as in disk mirroring, but each disk has a dedicated controller for an added level of protection.

X5.2.3 RAID 1—This is the same as disk mirroring (see X5.2.1).

X5.2.4 RAID 5—RAID 5 can read and write blocks of information to different disks in an array, and it distributes parity information over all disks in the array. Parity is a mathematical representation of data held in the array.

X5.3 Tape Backup—On-line tape backup is an option for multitasking operating systems. Tape backup does not provide “hot swap” capability, and data must be reentered after a drive failure. Also on-line tape backup may slow the system operation to an unacceptable degree.

X5.3.1 ¼-in. Tape, capacities to about 500 Mbytes.
X5.3.2 Digital Audio Tape (DAT), capacities to about 4 Gbytes (8 Gbytes with data compression).
X5.3.3 Video, 8 technology, capacities to about 5 Gbytes. This is based on 8–track, 8–mm tape cartridges used in video camcorders.

X6. FIXED ANTENNAS

X6.1 Scope—This appendix is intended to provide information of the types of fixed antennas commonly provided for navigation, communication, and collision avoidance.

X6.2 Classes—For purposes of this appendix, the following classes of antennas are considered:

X6.2.1 Omnidirectional Transmitting.
X6.2.2 Omnidirectional Receiving.
X6.2.3 Directional Transmitting.
X6.2.4 Directional Receiving.
X6.2.5 Rotating Transmitting/Receiving.

X6.3 Required Antenna Installations for Ocean Area A3 (Typical):

<table>
<thead>
<tr>
<th>System</th>
<th>Type Antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statcom A and B, suitable for telex, telephony, data and voice communication</td>
<td>Automatic directional transmitting/receiving, 1.5 to 1.65 GHz</td>
</tr>
<tr>
<td>Statcom C, telex only Satnav</td>
<td>Omnidirectional, 1.5 to 1.65 GHz</td>
</tr>
<tr>
<td>X-band radar system</td>
<td>Rotating transmitting/receiving—10 cm</td>
</tr>
<tr>
<td>S-band radar system</td>
<td>Rotating transmitting/receiving—3 cm</td>
</tr>
<tr>
<td>MF/HF transceiver for telephony, digital selective calling, direct printing telegraphy, general communications, range &lt;500 km</td>
<td>Large whip antenna as main with wire antenna as reserve</td>
</tr>
<tr>
<td>MF/HF watch receiver 2182 kHz</td>
<td>Same as above</td>
</tr>
<tr>
<td>MF alarm generator</td>
<td>Whip antenna</td>
</tr>
<tr>
<td>MF 2182-kHz direction finder</td>
<td>DF loop aerial and a short wire or whip</td>
</tr>
<tr>
<td>Navtex system</td>
<td>Whp</td>
</tr>
<tr>
<td>Inmarsat EG C receiver</td>
<td>Whp</td>
</tr>
<tr>
<td>VHF transceivers</td>
<td>Whp</td>
</tr>
<tr>
<td>VHF watch receiver</td>
<td>Whp</td>
</tr>
</tbody>
</table>

X6.4 References:

X6.4.2 CCIR Recommendation 45, avoidance of interference from ship’s other radio communication apparatus on board.
X6.4.3 International Convention for the Safety of Life at Sea, 1974 as amended, Chapters III and IV.

X6.5 Types of Antennas:

X6.5.1 Omnidirectional Antennas.
X6.5.2 Radio Transmitting Antennas:
X6.5.2.1 Wire Antennas:
(a) LF communication, 30 to 300 kHz.
(b) MF communication, 300 kHz to 3 MHz.
(c) Emergency communication, 500 kHz.
X6.5.2.2 Whip and Dipole Antennas:
(a) MF communication, 300 kHz to 3 MHz.
(b) HF communication, 3 to 30 MHz.
(c) VHF communication, 30 to 300 MHz.
(d) UHF communication, 300 MHz to 3 GHz.
(e) Facsimile receiver, 3 to 30 MHz.
X6.5.3 Radio/Television Receiving Antennas:
X6.5.3.1 Wire Antennas:
(a) LF communication, 30 to 300 kHz.
(b) MF communication, 300 kHz to 3 MHz.
(c) Emergency communication, 500 kHz.
X6.5.3.2 Omnidirectional Radio and Television Central Antennas.
X6.5.4 Satellite Communication:
X6.5.4.1 Satcom A and B, telex, telephony, data and voice communication, automatic 1.5 to 1.65 GHz.
X6.5.5 Directional Transmitting/Receiving Antennas:
X6.5.5.1 Satcom C, data and telex only, omnidirectional antenna, 1.5 to 1.65 GHz.
X6.5.6 Navigational Antennas
X6.5.6.1 Hyperbolic Navigation Antennas:
(a) Omega System, 10 kHz.
(b) Loran System, 100 kHz.
(c) Decca System, 84 to 130 kHz.
X6.5.7 Global Positioning System (GPS):
L1 band—1575.42 MHz
L2 band—1227.6 MHz
X6.5.8 Navigational Radar Antennas.
X6.5.9 Rotating Transmitting/Receiver Antenna:
X band navigation radar, 8 to 12 GHz
S band navigation radar, 3 to 4 GHz

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1. Scope

1.1 The principal content of this guide provides a road map to implement a communication network applicable to ship and marine computer systems by:

1.1.1 Examining the relationship of digital communication protocols as a network technological infrastructure,
1.1.2 Outlining the basic building blocks of network topologies and transmission techniques associated with the implementation of transmission media in a network environment; and,
1.1.3 Identifying operating system and environments.

1.2 Using the Open System Interconnection (OSI) model, which provides a layered approach to network functionality and evaluation, common network communications protocols are identified and characterized in this guide according to lower and upper layer protocols corresponding to their degree and type of functionality.

1.3 Although it is desirable that network users, designers, and administrators recognize and understand every possible networking protocol, it is not possible to know the intimate details of every protocol specification. Accordingly, this guide is not intended to address fully every hardware and software protocol ever developed for commercial use, which spans a period of about 25 years. Instead, the user of this guide will be introduced to a brief overview of the majority of past and present protocols which may comprise a ship or marine internetwork, to include Local Area Networks (LANs), Wide Area Networks (WANs), and related hardware and software that provide such network interoperability and data transfer.

1.4 While this guide provides an understanding of the wide range of communication protocols, the user is recommended to consult the reference material for acquiring a more comprehensive understanding of individual communication protocols. However, by examining the basic functions of protocols and reviewing the protocol characterization criteria identified in this guide, the user will be more apt to understanding other protocols not mentioned or addressed herein.

2. Referenced Documents

2.1 ASTM Standards:
E 1013 Terminology Relating to Computerized Systems
2.2 ANSI Standards:
X3T9.5 High Speed Local Network
X3.139 Fiber Distributed Data Interface (FDDI) – Token Ring Media Access Control (MAC)
X3.148 Fiber Distributed Data Interface (FDDI)– Token Ring Physical Layer Protocol (PHY)
X3.166 Fiber Distributed Data Interface (FDDI) – Token Ring Physical Layer Medium Dependent (PMD)
X3.172 American National Standard Dictionary for Information Systems
2.3 IEEE Standards:
100 Standard Dictionary for Electrical and Electronic Terms
610 Standard Glossary for Software Engineering Terminology
610.7 Standard Glossary of Computer Networking Terminology
802.1 High Level Interface (Internetworking)
802.2 Logical Link Control
802.3 CSMA/CD Medium Access Control
802.4 Token Bus Medium Access Control
802.5 Token Ring Medium Access Control
802.6 Metropolitan Area Networking
802.8 Fiber Optic Technical Advisory Group
802.9 Local and Metropolitan Area Networks: Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers
803.5
2.4 ISO Standards:
7498 Information Processing Systems–Open Systems Interconnection–Basic Reference Model
9040/9041 Virtual Terminal (VT)
8831/8832 Job Transfer and Manipulation (JTM)
8571/8572 File Transfer Access Management (FTAM)

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1 This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.05 on Computer Applications.

4 Available from IEEE, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08854-1331.
3.2 Definitions of Terms Specific to This Standard:

3.2.1 bridge, n—a device that interconnects local or remote networks no matter what network protocol that is, TCP/IP or IPX, are involved. Bridges form a single logical network.

3.2.2 hub, n—a central location for the attachment of cables from nodes and other network components.

3.2.3 internetwork, n—a collection of LANs using different network operating systems that are connected to form a larger network.

3.2.4 LAN (local area network), n—a data communication system consisting of a collection of interconnected computers, sharing applications, data and peripherals.

3.2.5 network operating system (NOS), n—the software for a network that runs in a file server and control access to files and other resources from multiple users.

3.2.6 node(s), n—any intelligent device connected to the network. This includes terminal servers, host computers, and any other devices, such as printers and terminals, that are directly connected to the network.

3.2.7 protocol, n—a standard method of communicating over a network.

3.2.8 repeater, n—a network device that repeats signals from one cable onto one or more other cables, while restoring signal timing and waveforms.

3.2.9 router, n—a device capable of filtering/forwarding packets based upon data link layer information.

3.2.10 server, n—a device that stores data for network users and provides network access to that data.

3.2.11 topology, n—the arrangement of the nodes and connecting hardware that comprises the network.

3.2.12 WAN (wide area network), n—a network using common carrier transmission services for transmission of data over a large geographical area.

4. Significance and Use

4.1 This guide is intended to provide an understanding of the wide range of communication protocols standards, allowing the user to understand better their applicability to shipboard networks and marine platform computerized systems. For computerized networks and systems, communication protocols are necessary for integrating various system devices, providing functionality between dissimilar subnetworks, or for enabling remote connections, either pier side or through geophysical communication technologies.

4.2 The wide variety and scope of digital communication protocol standards adds greatly to the complex decision process for specifying compatible protocols for system applications and related devices for the myriad of potential shipboard systems. However, the user must identify the initial networking requirements, so once the network protocols under evaluation are well understood, the decision process should determine the appropriate network protocols. Therefore, this guide is intended to reduce the complexity involved with protocol selection and implementation.

4.3 Network protocols define an agreed, quantifiable entity, or set of rules, by which user computers, system networks, and internetworking devices communicate and exchange information. Communication protocols specify essential networking guidelines, such as physical interface connections, or data
format and control operations between two communicating computers. Ship and marine digital communication protocol requirements are no different than their land-based networked counterparts. Both require standardized protocol selection, in various protocol categories, including LAN standards, WAN protocols, LAN/WAN protocols, network management, wiring hub configurations/operations, hardware platforms, operating systems, and network applications.

5. Origin of Protocol Development

5.1 Communication protocol standards have been developed or refined through three separate processes, identified as follows:

5.1.1 Defacto Protocol Standards—Acquired widespread use of a popular technique adopted by vendors and developers;
5.1.2 Dejur Protocol Standards—Standards making bodies; and,
5.1.3 Proprietary Protocol Standard—Private corporation-based protocols with limited interoperability.

5.2 The open standards approach is now the norm, which allows multiple protocol networking solutions to be available, and as a result, proprietary protocols are now becoming obsolete.

6. Local Network Interconnection

6.1 The characteristic of a local network is determined primarily by three factors: transmission medium, topology, and medium access control protocol.

6.1.1 The principal technological elements that determine the nature of a local network are the topology and transmission medium of the network. Together, it determines the type of data that may be transmitted, the speed and efficiency of communications, and the type of applications that a network may support.

6.1.2 Interconnecting a set of local networks is referred to as an internetworking. The local networks are interconnected by devices generically called gateways. Gateways provide a communication path so that data can be exchanged between networks.

6.2 Topology—The common topologies used for local networks are star, ring, and bus/tree (see Fig. 1).

6.2.1 Star Topology—In a star topology, a central switching element is used to connect all the nodes in the network. The central element uses circuit switching to establish a dedicated path between two stations wishing to communicate (see Fig. 1).

6.2.2 Ring Topology—The ring topology consists of a closed loop, with each node attached to a repeating element. Data circulate around the ring on a series of point-to-point data links between repeaters. A station wishing to transmit waits for its next turn and then sends data out onto the ring in the form of a packet (see Fig. 1).

6.2.3 Bus/Tree Topology—The bus or tree topology is characterized by the use of a multipoint medium. The bus is simply a special case of the tree, in which there is only one trunk, with no branches. Because all devices share a common communications medium, only one pair of devices on a bus or tree can communicate at a time. A distributed medium access protocol is used to determine which station may transmit (see Fig. 1).

6.3 Internetwork Topology—The common topologies used to support emerging networking topologies requiring the integration of data, video and voice, as well as higher transport bandwidth are backbone, hierarchical, and mesh (see Fig. 2).

6.3.1 Backbone—Backbone configurations are used in networking environments in which local networks are connected over high-speed backbone cables. Bridges and routers are used to manage the data passing between interconnected networks and the backbone (see Fig. 2).

6.3.2 Hierarchical—In the hierarchical configuration, star-configured hubs are wired to a central hub that handles interhub traffic. Routers and Asynchronous Transfer Mode (ATM) technology provide support to traffic intensive network applications requiring the integration of voice, video, and data (see Fig. 2).

6.3.3 Mesh—In mesh configurations, there are at least two pathways to each node. This is a common configuration in emerging high-speed enterprise networks requiring the integration of voice, video, and data. It is composed of internetworking devices, such as bridges, routers, and ATM technology. The internetworking devices provide efficient paths for data to travel from one point to another in this configuration. Mesh networks often are used because of reliability; when one path goes down, another can take over (see Fig. 2).

6.4 Cabling—Cabling falls into the following categories: coax, twisted pair, and fiber.

6.4.1 Coax:

6.4.1.1 Thicknet—The standard Thicknet is IEEE 802.3 10BASE5. It is a 0.4-in. diameter RG 4 50-Ω coaxial cable. It may be up to 500 m in length. A maximum of 100 devices can be attached to this cable.

6.4.1.2 ThinNet—The standard for ThinNet is IEEE 802.3 10BASE2. It is a 0.25-in. diameter RG58/A/U 50-Ω coaxial cable. It can be up to 185 m in length and have a maximum of 30 devices attached to it. Each device normally is attached at 0.5-m increments via a BNC T-connector. However, devices may be attached to an AUI cable and external transceiver.

6.4.2 Twisted Pair:

6.4.2.1 The standard for twisted pair is EIA/TIA-568. It is a 24-AWG telephone wire. The ends of the twisted pair wires are
composed of RJ-45 or RJ-11 telephone-style connectors. Each device connects to a network wiring hub which controls or passes the network signal. There are five category ratings for twisted pair wiring, LVL/CAT-1 through LVL/CAT-5.

6.4.2.2 There are two major types of twisted pair: unshielded twisted pair (UTP) and shielded twisted pair (STP). Environmental surroundings dictate what type of twisted pair is used. If the environment is prone to a high degree of electrical interference, STP is used.

6.4.3 **Optical Fiber**—See Table 1.

6.5 Table 2 provides a generalized comparison of the advantages and disadvantages of the technical characteristics of local networks, using the transmission medium as a frame of reference.

**Service Classes of Local Networks and Bandwidth Networks**—Computer networks that serve as components of a communication network provide support to a large multitude of service classes (see Table 3).

6.5.1 **Local Area Network (LAN)**—The LAN provides services to support a group of interconnected computers to share applications, data, and peripherals. Bandwidth service is from 1 to 10 Mbps.

6.5.2 **High-Speed Local Area Networks (HSLN)**—The HSLN provides a service in the range of 50 Mbps to 1 Gpbs. There are two key applications for HSLN: backend and backbone networks. A backend HSLN main function is to provide high end-to-end throughput between high-speed devices, such as servers and mass storage devices. A backbone HSLN provides a LAN or WAN that interconnects intermediate systems. Fiber optic cables are used as a transmission medium to internetwork topologies.

6.5.3 **Wide Area Network (WAN)**—A network that covers a large geographic area. The differences between WAN and LANs are as follows:

- **Economic**—WAN services are purchased; LANs are owned.
- **Technical**—WANs are made up of point-to-point links; LANs are shared-media.

6.6 **Medium Access Control Protocol**—To facilitate the sharing of the transmission among network stations, a proper medium access control scheme must be implemented to control, coordinate, and supervise the access of user information to and from the shared transmission medium:

- **LAN**—IEEE 802.3, IEEE 802.4, and IEEE 802.5 (CSMA/CD, token bus, and token ring) LAN protocols.

- **HSLN**—IEEE 802.2 (FDDI fiber token ring protocol) or IEEE 802.6 DQDB, ATM.

- **WAN**—X.25 Frame Relay, ATM.

---

**TABLE 1 Optical Fiber Cabling**

<table>
<thead>
<tr>
<th>Type</th>
<th>Light Source</th>
<th>Bandwidth</th>
<th>Primary Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single mode</td>
<td>laser</td>
<td>100 GHz</td>
<td>telephone traffic</td>
</tr>
<tr>
<td>Multimode</td>
<td>LED</td>
<td>1-2 GHz</td>
<td>data traffic</td>
</tr>
</tbody>
</table>

**FIG. 2 Internetwork Topology**
6.7 Internetworking (Gateways and Routers)—
Internetworking is the interconnection and interoperability of small-size local networks into existing networks. A local network should have the capability to support multiple protocols and allow difference environments to operate in parallel. Internetworking devices available for these services are Routers and Gateways.

6.7.1 Routers are devices that implement the network service. Routers are required to support multiple protocol stacks, each with its own routing protocols, and to allow these different environments to operate in parallel.

6.7.2 Gateways are applications specific that connect different architectures. It also provides translation services between different protocols.

6.8 Types of LANs—LANs are descriptive in their configuration at two levels: administrative relationship between nodes (stations) and physical and logical relationship among nodes.

6.8.1 Administrative Relationship Between Nodes (Station)—LANs are divided into server-based and peer-to-peer LANs. Server-based LAN (client server) controls access to some resource, such as a hard disk or printer, and serves as a host for the workstations connected to the server. A workstation request services, such as access to fields or programs on the hard disk or use of a printer, from a server.

6.8.1.1 Servers run the network operating system (NOS) software; workstations run client software that manages the communication between the workstation and the network.

6.8.1.2 Peer-to-peer LANs involve direct communications between computing devices without a dedicated server.

6.8.2 Physical and Logical Relationship Among Nodes—This has to do with the manner in how data is transmitted over a network. The physical is concerned with the topology, that is, bus, ring, or star, and logical refers to the method of data transport that is Ethernet, Token Ring, FDDI, ATM, and so forth.

6.9 Network Operating System (NOS)—The NOS runs on a server and is responsible for processing requests from workstations, for maintaining the network, and for controlling the services and devices available to users. An NOS may replace the native operating system or run as a program on top of the native operating system. Current NOS available are: NOVELL Netware, WINDOWS NT, LANtastic, BANYAN, IBM LAN Server, LAN Manager, AppleShare/AppleTalk.

6.10 Operating System (OS)—Operating systems bring together disparate computing resources and present the user with more convenient abstractions. These resources include devices for processing, storing, and transmitting information:

6.10.1 DOS (Disk Operating System)—Single-user operating system for the personal computer (PC).

6.10.2 Windows 95/NT—Microsoft windows product replacing Windows 3.1 and Windows for Workgroup 3.11. It provides system monitor utilities, remote access, network e-mail, fax capabilities, and file-and printer-sharing for both Windows-based and Netware-based clients.

6.10.3 OS/2—A multicasting operating system originally developed by IBM and Microsoft for use with Intel’s microprocessor and IBM’s Personal System/2 (PS/2) computers.

6.10.4 MAC OS—Apple’s Mac operating system.

6.10.5 UNIX—A multitasking, multiuser operating system developed by AT&T. This means that more than one user can use the same computer (programs, file system, memory, CPU) by logging in off of different ports (serial, Ethernet, Internet, and so forth).

6.11 Operating Environments—Operating environments provide computing flexibility and power to have more than one application active at the same time. They allow users to activate and switch several applications simultaneously.

6.11.1 Windows 3.1—This program provides an environment for running 16-bit Windows and DOS applications. It also supports multimedia, true-type fonts, compound documents (OLE), as well as drag-and-stop capabilities.

6.11.2 Windows for Workgroups—This program is a LAN-capable version of MS Windows 3.1 environment providing integrated file sharing, electronic mail (Microsoft Mail), and workgroup scheduling (Schedule +) capabilities. Windows for Workgroups 3.11 also supports 32-bit disk and file access.
6.11.3 Windows 95/NT—This program provides utilities, protocols, and services for a LAN environment running client software with support for Windows, Windows NT Workstation, Windows for Workgroups, MS-DOS, Macintosh, OS/2, and UNIX.

6.11.4 X Window System—A network-based windowing system. It provides an application interface for graphic window displays.

7. OSI Layers of Functionality

7.1 The OSI is a reference model put forth by the International Standards Organization (ISO) for communication between computer equipment and networks partitions computer communication functions into seven layers. Each layer provides a certain kind of service to the next higher layer. This service is provided by communicating with the peer entity in the same layer of the remote host using the service provided by the next lower layer. This model explains what each layer does. The model is often used to explain a suite of protocols, not just OSI, to allow computers to share resources across a network (see Table 4).

7.2 The content of each of the first four layers is dictated by the parameters of the network technology, and the upper three by the demands of the application user. As shown in Fig. 3, the lowest four layers, which are physical (1), data link (2), network (3), and transport (4), correspond roughly to protocols used in all networks. Physical distinguishes individual (0,1) bits, data link allows reliable transmission of groups of bits between adjacent computers, network provides safe routing data packets between distant source and destination computers, and transport lets programs running on different computers exchange sequences of possibly long messages.

7.3 The bottom three layers are implemented by communications carrier hardware or by LAN interfaces. Transport software runs on user computers. The highest three layers, session (5), presentation (6), and application (7), are intended to serve the needs of the application or application-specific elements.

7.4 For WANs, the intermediate-node routing function, network layer, is important, but media access is simple, usually a maker of making a leased, dial-up connection or satellite. Conversely, for LANs and MANs, no routing decisions need be made, and the network layer is essentially absent, although the multiaccess protocol can become quite sophisticated.

8. Layers of Interconnection

8.1 The OSI model allows networks to be interconnected at Layers 1 through 3 and 7. Interconnections between LANs and WANs usually occur at Layers 2 through 4 except for protocol conversion between specific applications, such as electronic mail which occur at Layer 7. A generic LAN/WAN interconnection function must operate at the lower OSI layers.

8.2 Model Structure—The OSI presents an abstract reference model to describe the computer communications. A layering techniques is used to divide the functions in to distinct yet connected layers. The seven layers can be partitioned into two main infrastructures, the lowest three layers provide internetworking services and the upper four layers are the users of these services. The upper layers, together, provide common network application services. One of the layers, the Transport Layer (4), serves as the boundary between the network-specific elements and the application-specific elements (see Fig. 4): 8.2.1 Lower layer infrastructure providing the end-to-end services responsible for data transfer.

8.2.2 Upper layer infrastructure providing the application services responsible for information transfer.

8.2.3 Each layer provides a well-defined function. Conceptually, these layers can be considered as performing one of two functions:

8.2.3.1 Network-Dependent Functions, lower layer.

8.2.3.2 Application-Oriented Functions, upper layer.

8.2.4 Thus when interconnecting networks, communication services are characterized by the following:

8.2.4.1 Data Link Protocol—Ethernet, Token Ring, FDDI, and ATM.

8.2.4.2 Network Protocol—IP, IPX, TCP, IPVINES, NETBIOS, and NETBEUL.

8.2.4.3 Higher Level Protocol (NOS)—Netware, Appletalk, Banyan VINES, Windows NT, IBM OS/2 LAN Manager, and so forth.

8.2.5 A canonical form of a layered communication protocol is illustrated in Fig. 5.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Application</td>
<td>Provides end-user services, such as application layer file transfers, electronic messages, virtual terminal emulation, remote database access, and network management. The end user interacts with the application user.</td>
</tr>
<tr>
<td>6</td>
<td>Presentation</td>
<td>Provides for the representation of information that is communicated between or referred to by application processes.</td>
</tr>
<tr>
<td>5</td>
<td>Session</td>
<td>Provides the means to organize and synchronize the dialog between application processes and manage their data.</td>
</tr>
<tr>
<td>4</td>
<td>Transport</td>
<td>Provides the transparent transfer of data between systems.</td>
</tr>
<tr>
<td>3</td>
<td>Network</td>
<td>Provides routing and relaying through immediate system. In intermediate systems in which there is no application program involved in the communication, the packets are only processed by the lower three layers.</td>
</tr>
<tr>
<td>2</td>
<td>Data link</td>
<td>Provides for the transfer of data between directly connected systems and detects any errors in the transfer.</td>
</tr>
<tr>
<td>1</td>
<td>Physical</td>
<td>Provides the transparent transmission of bit streams between systems including relaying through different media.</td>
</tr>
</tbody>
</table>

9.1 The characterization of common network protocols based on the layers of the OSI reference model provides a comparative technique to separate the various communication protocols into two categories. This perspective characterizes communication protocols based on their functionality and operations. By examining the seven layers of the OSI reference model, a lower and upper layer grouping for protocol characterization is developed to provide a better understanding for subsequent protocol selection for shipboard systems. This upper and lower layer characterization perspective is not perfect. Some communications protocols do not correspond exactly to the OSI layers in terms of functionality, while another popular protocol suite similar to the entire OSI network model does not fully correspond exactly to all the OSI layers.

9.2 The communication protocols described in this guide, which are based on the two lowest layers, the data link and physical layers of the OSI model, may differ among themselves with respect to levels of maturity and degree of commercial implementation. These lower layer protocols consists of a mixture of LAN and WAN technology protocols.

9.3 Upper layer protocols, in contrast, are often found to be families, or suites of protocols, developed as total networking solutions which mainly were developed as proprietary, corporate-based networking schemes. In addition, many upper layer protocols support integration with other upper and lower level protocols, enhancing their popularity and implementation possibilities with dissimilar protocols. Several of these protocols described in this guide were developed by standard groups, although sometimes only portions of the “dejure” protocol suites have been adopted commercially for certain applications.

10. Lower Level Protocols

10.1 The lower level protocols are the standards, specifications, and physical characteristics associated with the implementation of transmission media in a local network environment.

10.1.1 Ethernet—Ethernet is based on IEEE 802.3 standards. The standards that define IEEE 802.3 (see Table 5) networks have been given names that follow the form “s type 1.” The S refers to the speed of the network in Mbps, type is BASE for baseband and BROAD for broadband, and I refers to the maximum segment length in 100–m multiples. Table 5 shows the operating characteristics of three currently defined IEEE 802.3 networks to Ethernet.

10.1.2 Token Ring—Token ring is based on IEEE 802.5 standards. It can be either a 4- or 16-Mbps LAN. Instead of connecting to HUB, the lobe runs connect to either a multi-station access unit (MAU) or cable access unit (CAU). A maximum of 260 devices can be connected to a MAU or CAU star-wired ring, depending on the type of cable interface. IBM supports up to 260 devices attached to a MAU via the IBM cabling. With UTP, only 72 can be connected to a MAU and 144 to a CAU. See Table 6.

10.1.3 Fiber Distributed Data Interface—FDDI is based on IEEE 802.8 standards. FDDI networks operate at 100 Mbps over either fiber optic or twisted pair transmission media, using a counter-rotating redundant, dual-ring topology. The total length of the dual ring may not exceed 100 km (or 200 KM when wrapped or connected during a fault condition), with a maximum of 500 attached stations.

10.1.4 X.25 (see Fig. 6)—X.25 is a packet-switched network not transparent to attached stations, even during the data transfer phase. At a minimum, the network layer protocol must provide a service for transferring data between stations. This service may be either a virtual-circuit service (connection-oriented) or a datagram service (connectionless). Most public

<table>
<thead>
<tr>
<th>Operational Characteristics</th>
<th>Ethernet</th>
<th>10BASE5</th>
<th>10BASE2</th>
<th>10BASET</th>
<th>10BASEF</th>
<th>100BASET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating rate, Mbps</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Type of signaling</td>
<td>baseband</td>
<td>baseband</td>
<td>baseband</td>
<td>baseband</td>
<td>baseband</td>
<td>baseband</td>
</tr>
<tr>
<td>Data encoding</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
</tr>
<tr>
<td>Max segment length, m</td>
<td>500</td>
<td>500</td>
<td>186</td>
<td>100</td>
<td>1000</td>
<td>10000</td>
</tr>
<tr>
<td>Stations/segment</td>
<td>100</td>
<td>100</td>
<td>30</td>
<td>12/Hub</td>
<td>—</td>
<td>12/Hub</td>
</tr>
<tr>
<td>Medium</td>
<td>50-Ω coaxial</td>
<td>50-Ω coaxial</td>
<td>50-Ω coaxial</td>
<td>twisted pair (UTP, STP)</td>
<td>optical fiber</td>
<td>twisted pair (UTP, STP)</td>
</tr>
<tr>
<td>Topology</td>
<td>bus</td>
<td>bus</td>
<td>bus</td>
<td>star</td>
<td>bus</td>
<td>star</td>
</tr>
</tbody>
</table>

* Based on IEEE 802.3 (CSMA/CD).
networks provide a virtual-circuit service. X.25 encompasses the first three layers of the OSI model.

10.1.4.1 Layer 1—The physical layer is concerned with electrical or signalling. It includes standards, such as V.35, X.21(BIS), EIA232C.

10.1.4.2 Layer 2—The data link layer manages the transfer of data units called frames from one open system to another. The data link layer specified in X.25 is called LAP-B (Link Access Procedure Balanced).

10.1.4.3 Layer 3—The X.25 Packet Level Protocol (PLP) provides network-routing functions and the multiplexing of simultaneous logical connections over a single physical connection.

10.1.5 Frame Relay—Frame relay is a connection-oriented, fast-packet data service, conceptually similar to X.25. Whereas X.25 has three protocol layers and provides a guaranteed, virtual circuit packet delivery service, frame relay has only two layers of protocol (physical and data link layer) and relies on higher-layer protocols for end-to-end message assurance (see Fig. 6).

10.1.5.1 Frame relay is data link protocol. Frame relay service is viewed as one of the more versatile packet-switched technologies available for efficiently linking geographically separate organizations. Frame relay generally is deployed in larger internetworks. Table 8 shows the TCP/IP layers in relation to the seven layer OSI model.

11. Upper Layer Protocols

11.1 Upper layer protocols provide access to and control of the network environment, its applications, and data. The lower layers are used to exchange information.

11.2 ISO Architecture (see Table 7)—The ISO protocols are intended to standardize the by-products of network software and hardware development. The seven-layer ISO architectural model includes physical and data link layers that allow other protocol stacks to exist on the same media. OSI protocols include IEEE 802.2, 802.3, 803.5, ANSI FDDI X.21, V.35, X.25, and so forth. OSI also offers both a connectionless and connection-oriented network layer service.

11.3 TCP/IP—TCP/IP is a protocol suite. It is termed a suite because it is a family of protocols that can be used independently of each other. TCP/IP is not dependent on any particular physical connection. It was designed to connect subnetworks to larger internetworks. Table 7 shows the TCP/IP layers in relation to the seven layer OSI model.

11.3.1 TCP is a connection-oriented transport layer protocol that uses the connectionless services of IP to ensure the reliable delivery of data. Connection-oriented services establish link between two devices on a LAN. This link stays active for the length of a data transmission and can be closed when the transfer is furnished. With connectionless services, there is no requirement to establish a link between a source and destination device before data transmission can begin. Connectionless services are capable of sending data packets to multiple destinations, while connection-oriented services cannot.

11.3.2 TCP/IP provides important services, such as file transfer, e-mail, and remote login across a large number of distributed client and server systems. TCP/IP was introduced with UNIX, and then it was later incorporated into the IBM environment.

### Table 6 Transmission Speeds

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Transmission Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM Type 1</td>
<td>4 Mbps; lobes can be up to 100 ft</td>
</tr>
<tr>
<td></td>
<td>16 Mbps lobes can be up to 500 ft</td>
</tr>
<tr>
<td>IBM Type 2</td>
<td>4 Mbps; lobes can be up to 500 ft</td>
</tr>
<tr>
<td></td>
<td>16 Mbps; lobes can be up to 164 ft</td>
</tr>
<tr>
<td>IBM Type 3</td>
<td>26 Mbps; lobes can be up to 328 ft or 100 m</td>
</tr>
</tbody>
</table>

### Table 7 Upper Layer Protocols

<table>
<thead>
<tr>
<th>Application</th>
<th>ISO 9040/9041 VT</th>
<th>ISO 8831/8832 JTM</th>
<th>ISO 8571/8572 FTAM</th>
<th>ISO 9595/9596 CMIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>ISO 8823/ITU-T X.226</td>
<td>Connection-Oriented Presentation Protocol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Session</td>
<td>ISO 8327/ITU-T X.225</td>
<td>Connection-Oriented Session Protocol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>ISO 8073/ITU-T X.224</td>
<td>Connection-Oriented Transport Protocol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data link</td>
<td>ISO 9314-2</td>
<td>FDDI</td>
<td>ISO 8802-3</td>
<td>CSMA/CD (BUS)</td>
</tr>
<tr>
<td></td>
<td>ISO 8802-4</td>
<td>ISO 8802-4</td>
<td>ISO 8802-5</td>
<td>ISO 7776</td>
</tr>
<tr>
<td></td>
<td>Token Bus</td>
<td>Token Bus</td>
<td>Token Ring</td>
<td>ITU-T X.25 (LAP/LAPB)</td>
</tr>
<tr>
<td></td>
<td>ISO 7809</td>
<td>HDLC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Options from EIA , ITU-T, IEEE, and so forth</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11.3.3 To ensure that multivendor, multiplatform systems could communicate, the original design was based on open system standards. Because of this design, TCP/IP is platform independent in that it operates in a similar manner no matter what the platform. This is synonymous with interoperability, a key strategy for choosing and using protocols.

11.4 **NETWARE IPX/SPX**—Novell Netware protocols comply to the OSI model. The upper five layers provide file and printer sharing and support for various applications, such as electronic mail transfer, database access, and other dedicated NOS services (that is SNA, TCP/IP, AppleTalk, and OSI). The Internetwork Packet Exchange (IPX) (see Table 9) is a Netware protocol used to move data across a Novell network. The IPX packet deals directly with routers to move data across Novell NetWare Internetworks. IPX is a result of Novell’s efforts to add new services and features to the original Xerox XNS protocols.

11.4.1 IPX uses the Sequenced Packet Exchange (SPX) protocol to provide applications with reliable, connection-oriented data transport service. In the OSI model, IPX conforms to the network layer and SPX the transport layer.

11.5 **Systems Network Architecture (SNA)**—SNA is IBM’s proprietary networking protocol. SNA was designed to operate at the data link layer of the OSI model. The SNA network is a host-terminal environment because the mainframe acts as a host system, which is accessed by display devices called terminals.

11.6 **Advanced Peer-to-Peer Networking (APPN)**—APPN is IBM’s proprietary networking protocol. It is an enhancement to SNA to provide support for distributed applications in IBM networks, such as mainframes, AS/400s, and PS/2s. APPN enables direct communication between users anywhere on the network, a feature SNA could not provide. Much like TCP/IP, APPN resides at Layers 3 and 4 of the OSI model, providing network and transport functionality.

11.7 **Apple Talk**—AppleTalk is an OSI-based, CSMA/CD LAN technology from Apple. It supports Apple’s proprietary LocalTalk access method, as well as Ethernet (EtherTalk), and token-ring (TokenTalk). The AppleTalk network manager and the LocalTalk access method are built into all MACs and Laser Writer printers, as well as many third-party devices. AppleTalk can run on PCs, VAXs, and UNIX workstations.

11.7.1 LocalTalk is Apple’s LAN access method that uses twisted pair wiring and transmits at 230.4 Kbps. It runs under AppleTalk (see Table 10) and uses a daisy chain topology that connects up to 32 devices at a distance of up to about 1000 ft. LocalTalk can be configured to work in bus, passive, star, and active star topologies.

11.7.2 At Layer 3, the Datagram Delivery Protocol (DDP) provides a connectionless datagram services. At Layer 4, in the AppleTalk architecture, the Name Binding Protocol (NBP) provides name-to-address association. Routing table content is provided by the Routing Table Maintenance Protocol. At Layer 5, the Zone Information Protocol (ZIP) provides means of localizing broadcast traffic.

11.8 **XEROX Network Systems (XNS)** (see Table 11)—The XNS architecture makes two basic assumptions about its users: the Internetwork's underlying LAN technology is Ethernet, and multiple Ethernets exists. The XNS protocol implementation provides five level layers and corresponds closely to the OSI model.

11.8.1 XNS Level 0 defines the transmission media protocols that provide the physical mechanism for packet transport.

---

### TABLE 8 TCP/IP Protocol Suite

<table>
<thead>
<tr>
<th>OSI Layer</th>
<th>Protocol Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>File Transfer</td>
</tr>
<tr>
<td>Presentation</td>
<td>File Transfer Protocol (FTP)RFC 959</td>
</tr>
<tr>
<td>Session</td>
<td>Simple Mail Transfer-Protocol (SMTP)RFC 821</td>
</tr>
<tr>
<td>Transport</td>
<td>Transmission Control ProtocolRFC 793</td>
</tr>
<tr>
<td>Network</td>
<td>Address Resolution</td>
</tr>
<tr>
<td>Data link</td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 9 The Internet Packet Exchange (IPX)

<table>
<thead>
<tr>
<th>OSI Layer</th>
<th>Netware Protocol Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Application</td>
</tr>
<tr>
<td>Presentation</td>
<td></td>
</tr>
<tr>
<td>Session</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Sequential Packet Exchange (SPX)</td>
</tr>
<tr>
<td>Network</td>
<td>(IPX) Internet Packet Exchange</td>
</tr>
<tr>
<td>Data link</td>
<td>Ethernet Token Ring FDDI Others</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 10 LocalTalk LAN Access Method

<table>
<thead>
<tr>
<th>OSI Layer</th>
<th>AppleTalk Protocol Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Application</td>
</tr>
<tr>
<td>Presentation</td>
<td>Zone Information Protocol (ZIP)</td>
</tr>
<tr>
<td>Session</td>
<td>Routing Table Maintenance Protocol (RTMP)</td>
</tr>
<tr>
<td>Transport</td>
<td>Name Binding Protocol (NBP)</td>
</tr>
<tr>
<td>Network</td>
<td>Datagram Delivery Protocol (DDP)</td>
</tr>
<tr>
<td>Data link</td>
<td>Ethernet Token Ring FDDI Others</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
</tr>
</tbody>
</table>
11.8.2 XNS Level 1 defines the destination of the datagram (packet), and how it will get there. The Internetwork Datagram Protocol (IDP) is defined, as well as an addressing scheme to designate the various networks, hosts, and sockets through which that packet will originate, traverse, or terminate.

11.8.3 XNS Level 2 provides structures for the stream of datagrams. This level deals with the multitude of issues, such as sequencing, flow control, and retransmissions that are required of the OSI Transport Layer.

11.8.4 XNS Level 3 provides structures for the actual data that was transmitted and also controls various processes. As such, Level 3 covers the OSI session and presentation layers, and is designated the control protocols. XNS Level 4 deals with the various application protocols, similar to the OSI model.

11.9 DNAs (Digital Network Architecture) DECNet/OSI—DNA is the architecture, or master plan, for networking. DECNet/OST is an implementation of the architecture that is compliant with the ISO’s Open System Interconnection (OSI) Model in both number of layers, as well as layer functionality (see Table 12). DECNet is a proprietary Digital Equipment Corporation (DEC) Protocol. DECNet is a host-to-host (peer-to-peer) communication network. DECNet supports both connectionless and connection-oriented network layers. Both network layers are implemented by OSI protocols.

11.10 Local Area Transport (LAT)—LAT is a proprietary Digital Equipment Corporation (DEC) protocol (see Table 13). LAT is a terminal-to-host, or terminal I/O network on an Ethernet. LAT is a lean and mean protocol stack whose only purpose in life is to move terminal I/O as fast as possible between host and terminals and printers. LAT approximately implements Layers 3, 4, and 5. LAT is nonroutable protocol stack, which can only exist on the Ethernet implementation of Layers 1 and 2. LAT is implemented on VAXen, Alpha AXPs, in terminal servers, such as DECservers, and PCs and Macintoshes running PATHWORKS.

11.11 NetBEUI (Microsoft—proprietary)—NetBIOS Extended User Interface (NetBEUI) is the native network protocol used by Microsoft’s Windows NT and Windows 95. NetBEUI is an enhanced version of NetBIOS protocol used by a network operating system (NOS), such as LAN Manager and LAN server. Systems that use NetBEUI, such as Windows NT, can communicate with other Windows NT systems, as well as workstations running Windows for Workgroups.

11.12 NetBIOS—NetBIOS (Network Basic/Input System) is a network protocol designed exclusively for use in LANs. NetBIOS, along with its API, provide support of peer-to-peer network functions and a simple interface for writing network applications. There is no routing layer in NetBIOS. This means that NetBIOS cannot provide internetworking capabilities. Other protocols, such as IP or IPX must be used for internetworking. NetBIOS provides session and transport services (Layers 4 and 5 of the OSI model). This NetBIOS often is used to establish a connection between devices.

12. Fault Tolerance in Communication Networks

12.1 Fault tolerance is achieved using one or more of several forms of redundancy, which is simply the addition of information, resources, or time beyond what is needed for a normal system operation. The redundancy can take one of several forms, including hardware redundancy, software redundancy, information redundancy, and time redundancy.

13. Implementing a Communication Network

13.1 There are many documents and articles that discuss actual network design. Network designers have a definite preference for standard-based solutions, including those for media, protocols, and topologies. Standard-based networking solutions have the aura of optimally conceived technology and the promise of low (commodity) cost and multivendor available networking equipment using common silicon-based implementations. Standards not only imply the preceding desirable features, but also, at least theoretically, guarantee interoperability of equipment from different vendors.

13.2 Topology Selection Decision Tree—See Fig. 7.

13.3 Network Environment Selection Decision Tree—See Fig. 8, Fig. 9, and Fig. 10.

13.4 Internetworking (LAN-to-LAN or LAN-to-WAN):

13.4.1 Identify transport protocols present or supported by LAN-to-LAN or LAN-to-WAN internetwork.

13.4.2 Is the transport protocol(s) identified in 13.3 proprietary?

13.4.3 Identify a common denominator transport protocol to facilitate internetworking: RECOMMENDED: TCP/IP.
13.4.4 Identify basic services to be provided: FILE TRANSFER, ELECTRONIC MAIL, ROUTING, REMOTE ACCESS (Terminal Emulation).

13.4.5 Verify interoperability of NOS: Yes–Use router; No–Use gateway.

14. Keywords

14.1 bus; internetwork; local area network (LAN); network operating system (NOS); operating system (OS); protocol; ring; star; topology; tree; wide area network (WAN)
FIG. 8 Network Environment Selection Decision Tree (continued in Fig. 9 and Fig. 10)
### FIG. 9 Network Environment Selection Decision Tree (continued from Fig. 8)

#### TABLE 12.2D

<table>
<thead>
<tr>
<th>Network Operating System (NOS)</th>
<th>Protocol Supported</th>
<th>Basic Network Services</th>
<th>Client OS Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novell Netware</td>
<td>IPX, TCP/IP, AppleTalk, OSI</td>
<td>File, Print, Messages, Email</td>
<td>DOS, Mac OS, OS2, UNIX, Windows 3.x, Windows 95/NT</td>
</tr>
<tr>
<td>Windows NT</td>
<td>TCP/IP, IPX, AppleTalk, NetBIOS</td>
<td>File, Print, Messages, Email</td>
<td>DOS, Mac OS, OS2, UNIX, Windows 3.x, Windows 95/NT</td>
</tr>
<tr>
<td>LANtastic</td>
<td>TCP/IP, IPX, NetBIOS</td>
<td>File, Print, Messages, Email</td>
<td>DOS, DEC VAX, OS2, UNIX, Windows 3.x, Windows 95/NT</td>
</tr>
<tr>
<td>Banyan</td>
<td>TCP/IP, IPX, AppleTalk, NetBIOS</td>
<td>File, Print, Messages, Email</td>
<td>DOS, Mac OS, OS2, Windows 3.x, UNIX</td>
</tr>
<tr>
<td>LAN Manager</td>
<td>TCP/IP, NetBIOS</td>
<td>File, Print, Messages, Email</td>
<td>DOS, OS2, Windows 3.x</td>
</tr>
<tr>
<td>IBM LAN Server</td>
<td>TCP/IP, NetBIOS</td>
<td>File, Print, Messages, Email</td>
<td>DOS, OS2, Windows 3.x</td>
</tr>
<tr>
<td>DEC Pathworks</td>
<td>TCP/IP, AppleTalk</td>
<td>File, Print, Messages, Email</td>
<td>DOS, OS2, Mac OS</td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TABLE 12.2E1 NOS SUPPORT CHART

<table>
<thead>
<tr>
<th>Network Operating System (NOS)</th>
<th>Type of LAN Service</th>
<th>NOS Client Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novell Netware</td>
<td>Server-based</td>
<td>IPX/SPX</td>
</tr>
<tr>
<td>Windows NT Server</td>
<td>Server-based</td>
<td>NDIS</td>
</tr>
<tr>
<td>LANtastic</td>
<td>Peer-to-Peer</td>
<td>NDIS</td>
</tr>
<tr>
<td>Windows for Workgroup</td>
<td>Peer-to-Peer</td>
<td>NDIS</td>
</tr>
<tr>
<td>Windows 95</td>
<td>Peer-to-Peer</td>
<td>NDIS</td>
</tr>
<tr>
<td>UNIX</td>
<td>Server-based or Peer-to-Peer</td>
<td>TCP/IP</td>
</tr>
<tr>
<td>Apple Share/Apple Talk</td>
<td>Server-based or Peer-to-Peer</td>
<td>EtherTalk or AppleTalk</td>
</tr>
<tr>
<td>The Internet</td>
<td>Peer-to-Peer</td>
<td>TCP/IP</td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TABLE 12.2E2 NOS TYPE OF SERVICE

FIG. 9 Network Environment Selection Decision Tree (continued from Fig. 8)
<table>
<thead>
<tr>
<th>Client Operating System</th>
<th>MS Windows 95</th>
<th>IBM OS/2</th>
<th>MS Windows NT</th>
<th>Apple MAC OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netware Bindery</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Netware NDS</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Netware login Scripts</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Windows NT</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Windows 95</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>OS/2 LAN Server</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Unix (NFS Server)</td>
<td>some are supported</td>
<td>optional NFS add-on</td>
<td>optional NFS add-on</td>
<td>optional NFS add-on</td>
</tr>
<tr>
<td>LANbasic</td>
<td>possible with real mode drivers</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>DEC Pathworks</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>AppleTalk</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>BANYAN Vines</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

**TABLE 12** 2E3 OS FEATURES CHART

FIG. 10 Network Environment Selection Decision Tree (continued from Fig. 8 and Fig. 9)
1. Scope

1.1 This specification covers the design, construction, test, and performance requirements for air or nitrogen system filters, referred to hereinafter as filters. These filters are intended to be installed in-line to protect equipment from particular contamination.

1.2 The values stated in this specification in inch-pounds units are to be regarded as the standard. The SI equivalent shown in parentheses are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
   F 992 Specification for Valve Label Plates
2.2 American Society of Mechanical Engineers (ASME):
   B1.1 United Screw Threads (UN and UNR Thread Form)
   B1.20.1 Pipe Threads, General Purpose (Inch)
   B16.11 Forged Steel Fittings, Socket-Welding and Threaded
   B16.25 Butt Welding Ends
   B16.34 Flanged, Threaded, and Welded Ends
2.3 Society of Automotive Engineers (SAE):
   ARP 901 Aerospace Recommended Practice—Bubble-Point Test Method
2.4 Military Standards and Specifications:
   MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
   MIL-STD-740-1 Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment
   MS16142 Boss, Gasket Seal Straight Thread Tube Fitting, Standard Dimensions for

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


4 Available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096.

5 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver-Brazing, General Specifications for

2.5 Naval SEA Systems Command (NAVSEA): Government Drawings:
   NAVSEA 803-1385884 Unions, Fittings and Adapters Butt and Socket Welding 6000 PSI, WOG, NPS
   NAVSEA 803-1385943 Unions, Silver Brazing 3000 PSI, WOG, NPS, for UT Inspection
   NAVSEA 803-1385946 Unions, Bronze Silver Brazing, WOG for UT Inspection

3. Terminology

3.1 Definitions:

3.1.1 absolute contaminant removal rating—the smallest size of contaminant as defined in ARP 901 that the filter will retain with 100 % efficiency by weight.
3.1.2 bubble point—the pressure differential across a submerged filter element required to produce a visible and steady stream of air bubbles. Correlation between bubble point and contaminant removal capability provides an economical means to test for contaminant removal capability on a production basis. The bubble point indicates the maximum pore size of the filter media under static conditions.
3.1.3 bubble-tight—no visible leakage over a 3-min period using either water submersion or the application of bubble fluid for detection.
3.1.4 clean filter element pressure drop—the pressure drop across the filter element when it is new or uncontaminated.
3.1.5 cleanable filter element—a filter element that, after being contaminated to its dirt-holding capacity (contaminated filter element pressure drop), can be restored by cleaning to operational condition and with a pressure drop not exceeding the required clean filter element pressure drop.
3.1.6 contaminant removal rating—this is a measure of the size of contaminants that the filter can remove from the flow stream.
3.1.7 contaminated filter element pressure drop—the pressure drop across the filter element when it is contaminated to the point where cleaning or replacement is required.
3.1.8 differential pressure indicator actuation pressure—the pressure drop across the filter element at which the differential pressure indicator actuates.

3.1.9 disposable filter element—a filter element that, after being contaminated to its dirt-holding capacity (contaminated filter element pressure drop), cannot be restored to operational conditions and thereafter should be replaced.

3.1.10 external leakage—leakage that escapes to atmosphere.

3.1.11 filter element bypass full-flow differential pressure—the pressure drop across the filter element at which the filter bypass is passing the full-flow rating of the filter.

3.1.12 filter element bypass reseat differential pressure—the pressure drop across the filter element at which the filter bypass reseats after passing the full-flow rating of the filter.

3.1.13 filter element bypass set differential pressure—the pressure drop across the filter element at which the filter bypass opens.

3.1.14 filter element collapse strength—the maximum pressure drop or differential across the filter element that the element must withstand without collapse, damage, or impairment of performance capabilities.

3.1.15 filter element contaminant-holding capacity—also commonly termed “dirt capacity.” The amount of a contaminant, expressed in weight, that the element can hold when its resistance to flow causes a pressure drop equal to the contaminated filter element pressure drop.

3.1.16 filter element pressure drop—the pressure drop across the filter element.

3.1.17 filter housing pressure drop—the pressure drop accounted for by the filter housing.

3.1.18 filter pressure drop—the pressure drop across the entire filter (element and housing) at any given flow rate of the service fluid (air or nitrogen).

3.1.19 flow capacity—the maximum flow rate that the filter is required to pass.

3.1.20 hydrostatic shell test pressure—the hydrostatic test pressure that the filter is required to withstand without damage. The filter must be capable of meeting all performance requirements after the shell test pressure has been removed.

3.1.21 media migration—any material released into the flow stream by the filter media and its materials of construction. This term refers to the tendency of the filter media or “built-in” contamination, such as, welding scale, metal particles, or air-borne dust combined with the media during its manufacture, to leave the filter and shed or migrate into the flow stream.

3.1.22 nominal contaminant removal rating—the smallest size of contaminant as defined in ARP 901 that the filter will retain with 98% efficiency by weight.

3.1.23 operating pressure—the pressure within the filter during service.

3.1.24 pressure ratings—the pressure rating of the filter shall be defined in the documents listed in Table 1. The pressure rating for a filter is the maximum allowable working (service) pressure at 100°F (38°C).

---

**TABLE 1 Filter Inlet and Outlet End Connections**

<table>
<thead>
<tr>
<th>Type of End Connection</th>
<th>Pressure Rating</th>
<th>Applicable Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt-welded</td>
<td>ASME B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ASME B16.25</td>
</tr>
<tr>
<td>Socket-welded</td>
<td>ASME B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ASME B16.11</td>
</tr>
<tr>
<td>Threaded (tapered pipe thread)</td>
<td>ASME B16.34 Class 150, 300, 400, 600, 900, 1500, or 2500</td>
<td>ASME B1.20.1 and ASME B16.11</td>
</tr>
<tr>
<td>Union-end,a silver-brazed</td>
<td>MIL-F-1183 (O-ring type) 400 lb/in.² (2.758 MPa)</td>
<td>MIL-F-1183 (O-ring type) 400 lb/in.² (2.758 MPa)</td>
</tr>
<tr>
<td>Union-end,a silver-brazed</td>
<td>803-1385946 1500</td>
<td>803-1385946 1500</td>
</tr>
<tr>
<td>Union-end,a silver-brazed</td>
<td>803-1385943 3000</td>
<td>803-1385943 3000</td>
</tr>
<tr>
<td>Union-end,a butt/socket weld</td>
<td>803-1385884 6000</td>
<td>803-1385884 6000</td>
</tr>
<tr>
<td>Other, as specified</td>
<td>as specified</td>
<td>as specified</td>
</tr>
</tbody>
</table>

*aFor union inlet and outlet connections, only the pertinent dimensions listed in the applicable documents (military specification or NAVESA requirements) shall apply. The filter shall be supplied with the thread pieces only, without the tail pieces and union nuts.

4. Classification

4.1 Filters shall be of the following types, compositions, styles, pressure ratings, sizes, end connections, and contamination removal ratings, as specified in Section 5.

4.1.1 Filter Element Type:

4.1.1.1 Type I—Disposable.

4.1.1.2 Type II—Cleanable.

4.1.2 Filter Element Bypass Composition:

4.1.2.1 Composition A: with bypass.

4.1.2.2 Composition B: without bypass.

4.1.3 Filter Element Differential Indicator Style:

4.1.3.1 Style I: with differential pressure indicator.

4.1.3.2 Style II: without differential pressure indicator.

4.2 Pressure Ratings—Filters shall have pressure ratings selected from those listed in Table 1 and specified in Section 5. The pressure rating selected shall be the same for both the filter inlet and outlet.

4.3 Size—Filter sizes shall be ¼ NPS (13.5 mm), ½ NPS (21.3 mm), ¾ NPS (26.9 mm), 1 NPS (33.7 mm), 1¼ NPS (42.4 mm), 1½ NPS (48.3 mm), and 2 NPS (60.3 mm) or as specified in Section 5 (see Table 2).

4.4 End Connections—Filters shall have inlet and outlet end connections selected from those listed in Table 1 and specified in Section 5. Inlet and outlet connections shall be identical.

---

**TABLE 2 Filter Performance Characteristics**

<table>
<thead>
<tr>
<th>Filter Size, NPS</th>
<th>Minimum Dirt-Holding Capacity Grams AC Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ (13.5 mm)</td>
<td>6.0</td>
</tr>
<tr>
<td>½ (21.3 mm)</td>
<td>6.0</td>
</tr>
<tr>
<td>¾ (26.9)</td>
<td>10.0</td>
</tr>
<tr>
<td>1 (33.7 mm)</td>
<td>12.0</td>
</tr>
<tr>
<td>1¼ (42.4 mm)</td>
<td>12.0</td>
</tr>
<tr>
<td>1½ (48.3 mm)</td>
<td>14.0</td>
</tr>
<tr>
<td>2 (60.3 mm)</td>
<td>16.0</td>
</tr>
<tr>
<td>As specified</td>
<td>as specified</td>
</tr>
</tbody>
</table>
4.5 Contamination Removal Ratings—Filters shall have contamination removal ratings selected from the following three categories: 20 µm nominal/50 µm absolute, 5 µm nominal/18 µm absolute, and 0.4 µm nominal/5 µm absolute. The contamination rating selected shall be specified in Section 5.

5. Ordering Information

5.1 Ordering documentation for filters under the specification shall include the following information, as required, to describe the equipment adequately.

5.1.1 ASTM designation and year of issue,
5.1.2 Title, number, and date of this specification,
5.1.3 Filter element type (see 4.1.1),
5.1.4 Filter element bypass composition (see 4.1.2),
5.1.5 Filter element differential pressure indicator style (see 4.1.3),
5.1.6 Filter pressure rating (see 4.2),
5.1.7 Size (see 4.3),
5.1.8 End connections (see 4.4),
5.1.9 Contaminant removal rating, absolute/nominal (see 4.5),
5.1.10 Maximum filter operating pressure,
5.1.11 Flow capacity required (see 7.1, S1.3),
5.1.12 Supplementary requirements, if any ($1.0 through $4.0), and
5.1.13 Maximum vibration frequency and amplitude, if other than specified (see S1.8).

6. Filter Design and Construction

6.1 Filters shall incorporate the design features specified in 6.1.1-6.1.6.

6.1.1 Materials of Construction—Materials shall be 300 series corrosion-resistant steel (SS304, 304L, 316, or 316L), or other materials selected to provide compatibility with the line medium, weldability, and corrosion resistance without requiring painting, coating, or plating. The filter body and the filter bowl shall be weld repairable. Materials for contacting parts shall be selected to minimize electrolytic corrosion and galling.

6.1.2 Design Construction Requirements:

6.1.2.1 General Construction—The filter shall have a bolted flanged body and filter bowl to expedite removal of the filter element for cleaning or replacement.

6.1.2.2 Collapse Strength—The filter element shall be capable of withstanding a differential pressure equal to the maximum inlet pressure rating without structural degradation.

6.1.2.3 Automatic Bypass—When specified (see 5.1.4), the filter assembly shall incorporate an automatic bypass feature to bypass system fluid automatically around the filter element in the event of excessive flow restriction through the filter element. The automatic bypass shall be set in accordance with Table 3 and shall have a capacity equal to or greater than that of a clean filter assembly.

6.1.2.4 Filter Element Installation—Positive means shall prevent any play or looseness of the filter element in service and prevent cocking or misalignment during installation.

6.1.2.5 Filter Element Flow Direction—The filter element flow direction shall be from the outside to the inside surface of the element.

6.1.2.6 Cleanability—Cleanable filter elements shall be cleanable and reusable by means of scrubbing and washing the outside surface with detergent and tap water and blowing through with compressed air not exceeding 30-psig (207-kPa gage pressure). Once cleaned, the element shall be capable of meeting the requirements for a new element. Cleanable filter elements shall not be adversely affected by immersion in water and shall be capable of meeting the above criteria for not less than five cleaning and reuse cycles.

6.1.2.7 Differential Pressure Indicator—When specified (see 5.1.5), the filter body shall incorporate a non-electrical, “pop up” differential pressure indicator which senses the pressure drop across the element and actuates in accordance with Table 3. Once actuated, a red indicator button shall remain up until manually reset.

6.1.2.8 O-Ring Locations—O-rings in face-seal applications shall have the grooves located in the lower members to simplify assembly.

6.1.2.9 Pressure Envelope—The hydrostatic shell test pressures shall be 1.5 times the filter rated pressure at 100°F (38°C).

6.1.2.10 Connections—The inlet and outlet end connections of the filter shall be as specified in Table 1. Any exposed threads shall be protected by plastic caps for shipping.

6.1.2.11 Port Configuration—The filter body shall have in-line inlet and outlet end connections for installation into the piping system.

6.1.2.12 Pressure Lines—All pressure lines in the filter shall be internally ported.

6.1.2.13 Accessibility—The filter shall be fully and easily accessible for cleaning or repair without removal of the filter body from the line.

6.1.2.14 Threads—Threads shall be as specified in ASME B1.1. Where necessary, provisions shall be incorporated to prevent the accidental loosening of threaded parts. The design shall be such that standard wrenches can be used on all external bolting. Lock-wire shall not be used.

6.1.2.15 Interchangeability—The entire filter, including all associated piece parts, shall have part number identity and shall be replaceable from stock or the manufacturer on a nonselective and random basis. Parts having the same manufacturer’s

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**TABLE 3 Filter Pressure Drop Requirements**

<table>
<thead>
<tr>
<th>Filter Pressure Drop</th>
<th>Maximum Allowable Clean Element (see 7.1.5)</th>
<th>ΔP Indicator Actuation (see 7.1.5)</th>
<th>Maximum Allowable Contaminated Element (see 7.1.5)</th>
<th>Filter Element Bypass (see $1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example:</td>
<td>Operating pressure: 1000 psi (6895 kPa)</td>
<td>Maximum allowable clean element pressure drop: 25 psi (172 kPa)</td>
<td>ΔP indicator actuation: 47.5 to 52.5 psi (327 to 346 kPa)</td>
<td>Filter element bypass set pressure drop: 72.5 to 80 psi (500 to 552 kPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum allowable contaminated element pressure drop: 62.5 psi (431 kPa)</td>
<td>Filter element bypass set pressure drop: 72.5 to 80 psi (500 to 552 kPa)</td>
<td>Filter element bypass full-flow pressure drop: 82.5 to 92.5 psi (569 to 638 kPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Filter element bypass reseat pressure drop: 62.5 to 70 psi (431 to 483 kPa)</td>
<td>Filter element bypass reseat pressure drop: 62.5 to 70 psi (431 to 483 kPa)</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**—Percentages shown above shall read as percent of the operating pressure of the filter (see 3.1.23 and 5.1.10).
part number shall be directly interchangeable with each other with respect to installation (physical) and performance (function). Physically interchangeable assemblies, components, and parts are those that are capable of being readily installed, removed, or replaced without alteration, misalignment, or damage to parts being installed or adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.1.2.16 Nonmetallic Element Interchangeability—Nonmetallic elements, including but not limited to, cushions and O-rings, shall be treated as separately identified and readily replaceable parts.

6.1.2.17 Pressure Gage Ports—The filter shall be provided with threaded gage connection ports to permit attachment of pressure gages for sensing the inlet and outlet pressures. The gage connections shall be located to measure the pressure differential across the filter element accurately.

6.1.2.18 Springs—Any spring incorporated in the filter shall not be compressed solid during operation. Spring ends shall be squared and ground. Engagement or disengagement of parts against spring compression shall not be required.

6.1.3 Maintainability—The filter shall permit direct access for disassembly, repair, and reassembly of the filter element and all internal working parts and subassemblies when mounted for operation in the system. Maintenance shall require standard tools to the maximum extent possible. Any special tools required for maintenance shall be identified and shall be supplied as part of the filter.

6.1.4 Reversibility—The filter element, and all other parts in the filter, shall not be physically reversible unless they are also functionally reversible to preclude incorrect assembly.

6.1.5 Adjustments—There shall be no adjustments required in the filter during or after assembly other than the set points of a differential pressure indicator or an automatic bypass valve or both, where applicable.

6.1.6 Reliability—Except for cleaning or replacement of the filter element, periodic maintenance of the filter or any of its components shall not be required. There shall be no postassembly lubrication required.

7. Performance

7.1 Filters shall meet the performance requirements of 7.1.1-7.1.8.

7.1.1 Contaminant Removal Rating—The filter shall be capable of the levels of contaminant removal specified in the ordering information (see 4.5 and Section 5).

7.1.2 Flow Capacity—The flow capacity of the filter shall be as specified in 5.1.11 in standard cubic feet per minute (cubic metre per second) [at 60°F (16°C) and 14.7 psia (101 kPa absolute)]. The filter shall meet the specified maximum flow capacity, or any intermediate capacity, and shall operate while providing the specified filter contaminant removal rating. If an automatic bypass is specified (see 5.1.4), it shall also meet the flow capacity requirements of the filter.

7.1.3 External Leakage—Filter external leakage shall be bubble-tight at operating pressure conditions over a 3-min period.

7.1.4 Filter Element Contaminant-Holding Capacity—Solid particulate contaminant (dirt) holding capacity shall be as specified in Table 2.

7.1.5 Pressure Drop—The maximum allowable filter element clean and contaminated pressure drops shall be as specified in Table 3.

7.1.6 Differential Pressure (ΔP) Indicator Actuation Pressure—The pressure drop across the filter element at which the differential pressure indicator, where applicable, actuates shall be as specified in Table 3.

7.1.7 Filter Element Bypass Set, Full-Flow, and Reseat Differential Pressures—The set, full-flow, and reseat differential pressures of an automatic filter element bypass, where applicable, shall be as specified in Table 3.

7.1.8 Media Migration—There shall be no media migration.

8. Tests Required

8.1 Each filter shall pass the tests outlined in 8.1.1-8.1.4.

8.1.1 Visual Examination—The filter shall be examined visually to determine conformance with the ordering data and workmanship without disassembly.

8.1.2 Hydrostatic Shell Test—The filter shall be hydrostatically tested by applying pressure equal to 1.5 times the 100°F (38°C) rated pressure to the inlet and outlet ports, respectively, to check the structural integrity of the filter. The filter element may be removed for this test. Pressure shall be applied for a minimum of 3 min. Air or nitrogen gas may be used in lieu of water providing appropriate safety precautions are taken to minimize the risk associated with the use of a compressible gas. There shall be no external leakage, permanent distortion, or structural failure.

8.1.3 External Leakage Test—Air shall be applied at rated pressure to the filter. External leakage shall be checked using bubble fluid or by submerging the filter in water. There shall be no visible external leakage over a 3-min period.

8.1.4 Bubble Point Test—The filter element shall be tested to determine the initial bubble point. The bubble point test shall be performed in accordance with the procedure specified in ARP 901. To ensure the correct nominal contaminant removal rating and absolute contaminant removal rating, acceptance criterion shall have been previously established for the particular filter design being tested by an empirical correlation of the results of bubble point testing with actual particle retention testing as outlined in ARP 901.

9. Marking

9.1 Identification Plate—An identification plate of corrosion-resistant metal in accordance with Specification F 992: Types I, II, III, or IV shall be permanently attached to the filter and shall include the following information (some or all information may instead be stamped or etched directly on the filter body):

9.1.1 Manufacturer’s name,
9.1.2 ASTM designation and year of issue,
9.1.3 Operating conditions (inlet pressure and flow capacity),
9.1.4 Manufacturer’s model/part number,
9.1.5 Pressure rating,
9.1.6 Contamination removal rating (nominal/absolute in micrometre),
9.1.7 Replacement element part number,
9.1.8 Flow direction, if applicable.

10. Quality Assurance System

10.1 The manufacturer shall establish and maintain a quality assurance system that will ensure all the requirements of this specification are satisfied. This system shall also ensure that all filters will perform in a similar manner to those representative filters subjected to original testing.

10.2 A written description of the quality assurance system the manufacturer will use shall be available for review and acceptance by the inspection authority.

10.3 The purchaser reserves the right to witness the production tests and inspect the filters in the manufacturer’s plant to the extent specified on the purchase order.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements S1.0, S2.0, S3.0, or S4.0 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirements of the specification itself.

S1. Supplemental Tests

S1.1 Supplemental tests shall be conducted at a facility satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.2 through S1.11 and delineated in the ordering data. The tests may be conducted on representative filter sizes and pressure classes to qualify all sizes and pressure classes of filters, provided the filters are of the same type and design. Evidence of prior approval of these tests is acceptable.

S1.2 Element Collapse Test—Apply a pressure differential across the filter element equal to the pressure rating specified in Section 5 for 3 min. There shall be no structural damage to the filter element.

S1.3 Cleanability Test—The filter shall be subjected to sufficient contamination so that flow requirements cannot be met. It shall then be cleaned by the methods specified (see 6.1.2.6) to demonstrate cleanability. After cleaning, the element shall be capable of meeting the applicable flow and pressure drop criteria (see S1.5).

S1.4 Flow Capacity/Clean Filter Element Pressure Drop Test—Apply an inlet pressure equal to the maximum operating pressure of the filter (see 3.1.23 and 5.1.11). Flow shall be increased to the flow capacity of the filter. Pressure drop shall not exceed the allowable clean filter element pressure drop specified in Table 3. If the clean filter element pressure drop has been previously determined at a different inlet pressure, this test may be waived where calculations or previous testing are provided which verify an acceptable clean filter element pressure drop at the maximum operating pressure.

S1.5 Differential Pressure Indicator Actuation Pressure Test—Differential pressure across the filter element shall be increased until the differential pressure indicator actuates. The actuation pressure shall be as specified in Table 3. Once actuated, the red button shall remain in the up position until manually reset.

S1.6 Automatic Bypass Valve Set Differential Pressure Test—Differential pressure across the filter element shall be further increased until the automatic bypass valve opens. Differential pressure shall be further increased until the automatic bypass valve is fully open. Differential pressure shall then decreased until the automatic bypass valve reseats. The automatic bypass valve shall lift initially, then lift to pass the full-flow capacity, and reseat within the limits specified in Table 3. There shall be evidence of operational instability or damage.

S1.7 Seat Tightness Test—The differential pressure across the automatic bypass valve shall be increased to 95 % of its set pressure. The automatic bypass valve shall be bubble-tight (no visible evidence of leakage over a 3-min period using bubble fluid for detection or submerging a line from the outlet under water).

S1.8 Shock Test—The filter shall be subjected to and meet the high-impact shock tests for Grade A, Class I as specified in MIL-S-901 pressurized with water, air, or nitrogen to the maximum operating pressure. There shall be no structural damage to the filter. There shall be no degradation to the performance capability of the filters.

S1.9 Vibration Test—The filter shall be vibration tested in accordance with Type I of MIL-STD-167-1 pressurized with air or nitrogen to the maximum operating pressure. At frequencies up to and including 33 Hz (unless otherwise specified in the ordering information, Section 5), there shall be no resonance in the range of frequency tested. There shall be no structural damage or degradation to the performance capability of the filter.

S1.10 Noise Test—The filter shall be tested for airborne noise in accordance with MIL-STD-740-1. The noise (sound pressure level) shall not exceed 85 dBA observed at 1-m distance from the filter.

S1.11 Posttest Examination—The filter shall be disassembled and examined for any evidence of excessive wear, degradation, or impending damage or breakage.

S2. Technical Data Requirements

S2.1 Drawings—Assembly drawings or catalog sheets of the filter that clearly depict design shall be provided. The following shall also be included as part of, or in addition to, the drawing or catalog content:

S2.1.1 Bill of material listing specification, grade, condition, and any other data required to identify fully the properties
of the materials proposed. This shall include identifications, material and size designations, shore hardness, and any other data necessary to identify the parts fully.

S2.1.2 In cases in which standard commercial or military parts are or can be used, these shall be appropriately identified.

S2.1.3 Outline dimensions, disassembly space, location, and size of end connections and mounts.

S2.1.4 Estimated weight and center of gravity (vertical, longitudinal, and transverse).

S2.1.5 Recommended assembly torques or equivalent procedures for making up all joints and threaded assemblies.

S2.1.6 The following information shall be included: (1) pressure rating, (2) contaminant removal rating, (3) clean pressure drop at filter-rated flow capacity, (4) differential pressure indicator setting (Style I filters), and (5) automatic bypass valve setting (Composition A filters).

S2.2 Technical Manuals—Technical manuals shall provide a description, installation procedures, operation and maintenance instructions, and illustrated parts breakdown for the filter, organized as follows:

S2.2.1 Chapter 1—General information and safety precautions.

S2.2.2 Chapter 2—Operation.

S2.2.3 Chapter 3—Functional description.

S2.2.4 Chapter 4—Scheduled maintenance.

S2.2.5 Chapter 5—Troubleshooting.

S2.2.6 Chapter 6—Corrective maintenance.

S2.2.7 Chapter 7—Parts list.

S2.2.8 Chapter 8—Installation.

S2.3 In addition, the following shall be included as part of the technical manual contents:

S2.3.1 The assembly drawings for the filter, supplemented by additional illustrations where necessary to illustrate operation and maintenance adequately. These additional illustrations may consist of blowouts or partial or full sections and may eliminate extraneous lines and details to clarify the interaction of parts.

S2.3.2 Table listing wrench sizes and assembly torques (or other equivalent procedures) for making up all joints and threaded assemblies.

S2.3.3 Detailed disassembly and reassembly procedures. In addition to a section providing procedures for the complete disassembly and reassembly of the filter, maintenance and troubleshooting sections shall contain, or refer to, only the limited disassembly and reassembly required to accomplish each particular operation. This is intended to reduce the possibility of unnecessary disassembly and unnecessary disturbance of adjustments when performing specific or limited maintenance or troubleshooting operations.

S2.3.4 Adjustment procedures for the differential pressure indicator and the automatic bypass valve (where applicable).

S3. Quality Assurance

S3.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.

S3.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.

S3.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish and, from time to time, to alter whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organized freedom to identify quality control problems and to initiate, recommend, and provide solutions.

S3.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.

S3.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.

S3.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.

S3.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacturer. The manufacturer shall maintain control of material during the manufacturing process by a system that identifies status of material throughout all stages of manufacture.

S3.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions using documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.

S3.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.

S3.10 Welding—The quality control system shall include provisions for ensuring that welding conforms to specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made to the inspection authority if required.

S3.11 Nondestructive Examination—Provisions shall be made to use nondestructive examination, as necessary, to ensure that material and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer or qualified by a recognized national body or both, and their authorizations/qualification records shall be made available to the inspection authority if required.
X1. GUIDELINES FOR THE SELECTION AND INSTALLATION OF FILTERS

X1.1 Scope—This appendix provides general guidelines for the selection and installation of filters in air or nitrogen systems, and therefore, its use does not in any way relieve the user of his final responsibility in the selection and installation of filters.

X1.2 Contamination Removal Rating (also commonly termed: “filter rating” or “micrometre rating”)—The finer the contamination removal rating specified, the more frequently it will be necessary to clean (or replace) the filter element. Therefore, only the actual desired level of filtration required by a particular application, and as shown by design analysis or operating experience, should be specified.

X1.3 Filter Element Bypass—A filter element bypass should be specified for any application where a partial or full blockage of fluid flow is not acceptable. Some or all of the fluid flow under such circumstances will be unfiltered. Where a constant supply of filtered fluid is necessary, a multiple-filter approach should be considered. An adjustable filter element bypass allows setting (within the limits of adjustment provided) the pressure drop at which bypass of flow initiates.

X1.4 Permanent Versus Disposal Elements—Permanent filter elements are designed to provide specified performance repeatedly up to a specified number of cleaning from a contaminated condition. Disposable filter elements require replacement with a new like element each time they reach a contaminated condition. Permanent elements can reduce inventory requirements. Disposable elements can reduce initial costs and maintenance requirements.

X1.5 Contaminant-Holding Capacity—To a certain extent, contaminant-holding capacity is proportional to the flow...
capacity-pressure drop capabilities of a filter element. Different filter mediums, however, hold contaminants in different ways, giving different contaminant-holding capacities for any given initial (clean) flow capacity-pressure drop capability, and therefore, it is necessary to specify contaminant-holding capacity as a separate parameter.

X1.6 Differential Pressure Indicator—A filter element differential pressure indicator warns of a high contamination level before it reaches the point at which the flow of filtered fluid is no longer adequate to meet system requirements or a bypass will begin to open. An adjustable filter element differential pressure indicator allows setting (within the limits of adjustment provided) the pressure drop at which the indicator actuates.
Standard Specification for Special Requirements for Valves Used in Gaseous Oxygen Service

This standard is issued under the fixed designation F 1792; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the special requirements for valves used in gaseous oxygen service. It is intended that this specification be invoked as an additional requirement in conjunction with primary valve specifications.

1.2 The values stated in this specification in inch-pound units are to be regarded as the standard. The SI equivalent shown in parenthesis are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
   G 63 Guide for Evaluating Nonmetallic Materials for Oxygen Service
   G 88 Guide for Designing Systems for Oxygen Service
   G 93 Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments
   G 94 Guide for Evaluating Metals for Oxygen Service

2.2 American National Standards Institute (ANSI):
   B1.1 Unified Screw Threads

2.3 American Society of Mechanical Engineers (ASME):
   Boiler and Pressure Vessel Code

2.4 Military Standards and Specifications:
   MIL-V-5027 Valves, Check, Oxygen, High Pressure
   MIL-STD-278 Fabrication, Welding and Inspection; Cast-

3. Ordering Information

3.1 Ordering documentation for valves under this specification shall include the following information, as required, to describe the equipment adequately:

3.1.1 ASTM designation and year of issue.
3.1.2 Primary valve specification (see 1.1).
3.1.3 End preparations, if different than specified in 4.4.
3.1.4 Supplementary requirements, if any (see SI through S4).

4. Valve Design and Construction

4.1 Valves shall incorporate the features specified in 4.2-4.6.

4.2 Materials of Construction—Material requirements shall be as follows:

4.2.1 The pressure containing/retaining envelope (including any bolting, union nuts, or other fastening devices establishing the integrity of the pressure containing/retaining envelope), bellows (where applicable), and end nipples, shall be nickel-copper (70-30). Internal trim which is in contact with the line media shall be nickel-copper (70-30), bronze, nickel-aluminum-bronze, Inconel Alloy 600, brass, or other materials which are compatible with oxygen service.

4.2.2 Non-metallic seat, seat insert, or seals. These materials shall be from TFE, Reinforced TFE, CTFE, plastic in accordance with MIL-P-46122, Polyamide (Vespel), or PEEK. The materials for O-rings and gaskets shall be compatible for oxygen service.

4.2.3 Lubricants—Materials for lubricants shall be halocarbon (25-5S), Dupont (Krytox 240 AC, 240 AZ), Braycote 601, or other lubricants compatible with oxygen service.

4.2.4 Guidance on the selection of materials for oxygen service can be found in Guides G 63 and G 94. Guidance on designing systems for oxygen service can be found in Guide G 88.
4.3 General Requirements:

4.3.1 Fire Prevention—Valves shall be constructed to minimize the possibility of initiating ignition in gaseous oxygen service. This shall be accomplished by the following:

4.3.1.1 Materials for parts in contact with oxygen shall have the highest spontaneous ignition temperatures and the lowest impact sensitivities compatible with construction and performance limitations.

4.3.1.2 Surfaces in contact with oxygen shall be smooth with well-rounded edges and without sharp or thin sectioned protrusions (that is, all parts shall have a high ratio of volume-to-surface area). Sharp exterior corners are prohibited, and interior corners shall have fillets to prevent the retention or entrapment of machining chips, burrs, or foreign material.

4.3.1.3 Nonmetallic materials (O-rings, gaskets, etc.) other than the seating insert, if applicable, shall be well removed from the main flow path.

4.3.2 Fire Containment—Valves shall be constructed to minimize oxygen escape in the event of an internal or external fire. This shall be accomplished by the following:

4.3.2.1 Pressure-Boundary Sealing—Joints for the pressure-boundary seals shall provide an effective barrier to leakage in the event of damage or consumption of the non-metallic sealing elements by providing long, close fitting metal-to-metal leakage or flame paths.

4.3.2.2 Internal Seating—The seat design shall be such that in the event that the non-metallic seat is damaged, destroyed, or carried away, there will be a secondary metal-to-metal seat to minimize through seat leakage. The construction and location of the nonmetallic seals and seating inserts shall minimize the possibility of ignition under a pressure surge.

4.3.2.3 Pressure Surge—Valves shall be designed to prevent pressure surge, which could cause auto-ignition.

4.4 Design Features:

4.4.1 Manual valves shall be of the packless design, with the stem sealed by a bellows.

4.4.2 Threads—Threads shall conform to ANSI B1.1. Use of threads in contact with oxygen shall be minimized. Any threads wetted by oxygen shall be of rolled construction or shall be completely chamfered and deburred to prevent the possibility of sharp edges or machining burrs in contact with oxygen.

4.4.3 Cleaning—Prior to assembly and testing, valves shall be degreased and cleaned in accordance with Practice G 93, and thereafter maintained clean for oxygen service.

4.5 End Preparation—Unless otherwise specified (see Section 3), end preparation for the valves shall be as follows:

4.5.1 Valves shall be supplied with inline extension nipples welded directly to the valve body or fabricated as an integral part of the valve body. Nipples shall be of the same basic material as the body. The length and schedule of these nipples shall be as specified in Table 1.

4.6 Welding and Nondestructive Testing—Welding and nondestructive testing shall be in accordance with ASME Boiler and Pressure Vessel Code, Sections VIII and IX.

5. Marking

5.1 Identification Plates—A metallic corrosion-resisting identification plate shall be securely attached to the valve and shall indicate “Valve specially made for oxygen service”.

5.2 In addition, each valve shall be marked in accordance with their applicable primary valve specification requirements.

6. Quality Assurance System

6.1 The manufacturer shall establish and maintain a quality assurance system that will ensure all the requirements of this specification are satisfied.

6.2 A written description of the quality assurance system the manufacturer will use shall be available for review and acceptance by the inspection authority.

6.3 The purchaser reserves the right to witness any tests and inspect the valves in the manufacturer’s plant to the extent specified on the purchase order.

### TABLE 1 Length and Schedule of Extension Nipples

<table>
<thead>
<tr>
<th>Size of Valve, Pipe Schedule</th>
<th>Minimum Length of Extension, inches (Valve Center to End)</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ NPS to 1 NPS (13.5 mm to 33.7 mm)</td>
<td>80 7.00 (178 mm)</td>
</tr>
<tr>
<td>1-¼ NPS to 2-½ NPS (43.3 mm to 73.0 mm)</td>
<td>160 12.0 (305 mm)</td>
</tr>
</tbody>
</table>

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements S1, S2, S3, or S4 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

**S1. Supplemental Tests**

S1.1 Supplemental tests shall be conducted at a laboratory satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.2 through S1.4.

S1.2 Examination Prior to Testing—The valve(s) shall be examined visually to determine conformance with the ordering data, dimensions, and workmanship without disassembly.

S1.3 Nonmetallic Materials Compatibility Test—Materials shall be subjected to the ozone-resistance and oxygen-bomb tests as specified in MIL-V-5027, with test pressure applicable to the valve under test. No charring or deterioration is allowed.

S1.4 Nondestructive Testing—Nondestructive testing shall be in accordance with MIL-STD-271.
S2. Cleaning, Drying, Packaging, and Marking Requirements

S2.1 Valves shall be cleaned, dried, packaged, and marked in accordance with MIL-STD-1330. Packaging operations shall be accomplished in an area that will prevent valve contamination by hydrocarbons.

S3. Quality Assurance

S3.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.

S3.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.

S3.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

S3.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.

S3.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.

S3.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.

S3.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system that identified inspection status of material throughout all stages of manufacture.

S3.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions utilizing documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.

S3.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.

S3.10 Welding—The quality control system shall include provisions for ensuring that welding conforms to specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made available to the inspection authority if required.

S3.11 Nondestructive Examination—Provisions shall be made to utilize non-destructive examination, as necessary, to ensure that material and components comply with the specified requirements. Non-destructive examinations shall be authorized by their employer and/or qualified by a recognized national body, and their authorizations/qualification records shall be made available to the inspection authority if required.

S3.12 Non-Conforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.

S3.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.

S3.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of material during all stages of manufacture and shall be able to distinguish between inspected and non-inspected material.

S3.15 Calibration of Measurement and Test Equipment—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring and test equipment to be used in verifying conformance to the specified requirements. Such calibration shall be traceable to a national standard and calibration records shall be maintained.

S3.16 Records Maintenance—The manufacturer shall have a system for the maintenance of inspection records, photographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S3.17 Sample Forms—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S3.18 Inspection Authority—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with originals or copies of such documents.

S4. Special Fabrication Requirements

S4.1 Welding Requirements—Welding shall be in accordance with MIL-STD-278.
Designation: F 1793 – 97 (Reapproved 2004)

An American National Standard

Standard Specification for Automatic Shut-Off Valves (Also Known as Excess Flow Valves, EFV) for Air Or Nitrogen Service

This standard is issued under the fixed designation F 1793; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers self-contained automatic shut-off valves (also known as excess flow valves) for air or nitrogen service. They are intended to be installed as safety devices to quickly and automatically shut off flow under certain excess flow conditions caused by a downstream failure or casualty, such as a hose rupture.

1.2 The values stated in this specification in inch-pound units are to be regarded as the standard. The SI equivalents shown in parentheses are provided for information only.

2. Referenced Documents

2.1 ASTM Standards: 2
F 992 Specification for Valve Label Plates
2.2 American National Standards Institute (ANSI). 3
B1.1 Unified Screw Threads (UN and UNR Thread Form)
B1.20.1 Pipe Threads, General Purpose (Inch)
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.25 Butt welding Ends
B16.34 Valves—Flanged, Threaded, and Welded End
2.3 Military Standards and Specifications: 4
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-740-1 Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment
MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery Equipment and Systems, Requirements for
MIL-F-1183 Fitting, Pipe, Cast Bronze, Silver Brazing, General Specification for

2.4 Government Drawings: 4
NAVAL SEA SYSTEMS COMMAND (NAVSEA)
NAVSEA 803-1385884 Unions, Fittings and Adapters Butt and Socket Welding 6000 PSI, WOG, NPS
NAVSEA 803-1385943 Unions, Silver Brazing 3000 PSI, WOG, NPS, for UT Inspection
NAVSEA 803-1385946 Unions, Bronze Silver Brazing, WOG for UT Inspection

3. Terminology

3.1 Definitions:
3.1.1 automatic shut-off valve—automatic shut-off valves covered by this specification trip shut in response to the pressure differential across the valve.
3.1.2 bubble-tight—no visible leakage over a 3-min period using either water submersion or the application of bubble fluid for detection.
3.1.3 external leakage—leakage from the automatic shut-off valve that escapes to atmosphere.
3.1.4 hydrostatic shell test pressure—the hydrostatic shell test pressure that the automatic shut-off valve is required to withstand without damage. Automatic shut-off valve operation is not required during application of shell test pressure, but it must meet all performance requirements after the shell test pressure has been removed.
3.1.5 pressure ratings—the pressure ratings of the automatic shut-off valves shall be as defined in the documents listed in Table 1. The pressure ratings (also called pressure-temperature ratings) establish the maximum allowable working (service) pressures of a component (valve, end connections, and so forth) at various temperatures.
3.1.6 seat tightness—the ability of the automatic shut-off valve to prevent leakage from the valve-inlet to the valve-outlet.
3.1.7 set point—a combination of inlet pressure and flow, at which the valve trips shut.
3.1.8 set point accuracy—the band of accuracy of the automatic shut-off valve expressed as a range of flow rates at a given inlet pressure, established by the following two points:
TABLE 1 Pressure Ratings for Automatic Shut-Off Valves

<table>
<thead>
<tr>
<th>Type of End Connection</th>
<th>Pressure Rating</th>
<th>Applicable Documents for Dimensional Details of End Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt-welded</td>
<td>ANSI B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ANSI B16.25</td>
</tr>
<tr>
<td>Socket-welded</td>
<td>ANSI B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ANSI B16.11</td>
</tr>
<tr>
<td>Threaded (tapered pipe thread)</td>
<td>ANSI B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ANSI B1:20.1 and ANSI B16.11</td>
</tr>
<tr>
<td>Union-end. A</td>
<td>MIL-F-1183 (O-ring type)</td>
<td>MIL-F-1183 (O-ring type)</td>
</tr>
<tr>
<td>Silver-brazed</td>
<td>400 lb/in² (2.758 MPa)</td>
<td>400 lb/in² (2.758 MPa)</td>
</tr>
<tr>
<td>Union-end. A</td>
<td>803-1385946 1500 lb/in² (10.342 MPa)</td>
<td>803-1385946 1500 lb/in² (10.342 MPa)</td>
</tr>
<tr>
<td>Union-end. A</td>
<td>803-1385943 3000 lb/in² (20.684 MPa)</td>
<td>803-1385943 3000 lb/in² (20.684 MPa)</td>
</tr>
<tr>
<td>Silver-brazed</td>
<td>(20.684 MPa)</td>
<td>(20.684 MPa)</td>
</tr>
<tr>
<td>Union-end. A</td>
<td>803-1385884 6000 lb/in² (41.369 MPa)</td>
<td>803-1385884 6000 lb/in² (41.369 MPa)</td>
</tr>
<tr>
<td>Butt/socket weld</td>
<td>(41.369 MPa)</td>
<td>(41.369 MPa)</td>
</tr>
<tr>
<td>Other, as specified</td>
<td>As specified</td>
<td>As specified</td>
</tr>
</tbody>
</table>

A For Union inlet and outlet end connections, only the pertinent dimensions listed in the applicable documents (Military Specification or NAVSEA Requirements) shall apply. The valve shall be supplied with the thread-pieces only, without the tail-pieces and union-nuts.

3.1.8.1 Discussion—A combination of inlet pressure-flow, at or below which the automatic shut-off valve will not trip shut (valve will remain open) regardless of influences such as spring relaxation, mechanical shock or vibration, and so forth.

3.1.8.2 A combination of inlet pressure-flow, at or above which the automatic shut-off valve will trip shut (valve will not remain open) regardless of influences tending to resist closure such as breakloose friction, corrosion, or sludge, and so forth.

3.1.9 Set-point range—the range of set points over which the automatic shut-off valve can be adjusted. Expressed as a range of flow rates at a given inlet pressure.

4. Classification

4.1 Automatic shut-off valves shall be of the following types, styles, sizes, pressure ratings, and end connections:

4.1.1 Types:

4.1.1.1 Type I—Valves that can be adjusted or repaired without removing the valve from pipe line.

4.1.1.2 Type II—Valves that cannot be adjusted or repaired without removing the valve from pipe line.

4.1.2 Styles:

4.1.2.1 Style 1—Automatic Reset Construction—These valves are designed to limit the flow of air or nitrogen upon closure to a small predetermined level. These valves reset automatically once the service line downstream is made air or nitrogen-tight and pressure is equalized across the valve.

4.1.2.2 Style 2—Manual Reset Construction—These valves are designed to stop the flow of air or nitrogen upon closure. These valves must be manually reset.

4.1.3 Sizes—Automatic shut-off valves shall be of the following NPS sizes: ¼ (13.5 mm), ⅜ (17.2 mm), ½ (21.3 mm), ⅝ (26.9 mm), 1 (33.7 mm), 1¼ (42.4 mm), 1½ (48.3 mm), and 2 (60.3 mm). Unless otherwise specified in 5.0, the valve inlet size shall be the same as the outlet size.

4.1.4 Pressure Ratings—Automatic shut-off valves shall have pressure rating(s) selected (see 3.1.5) from Table 1. The pressure rating(s) selected shall be specified in Section 5.

inlet and outlet pressure ratings of the automatic shut-off valve shall be the same for any given valve.

4.1.5 End Connections—Automatic shut-off valves shall have end connections selected from those listed in Table 1 and specified in Section 5.

5. Ordering Information

5.1 Ordering documentation for automatic shut-off valves under this specification shall include the following information, as required, to describe the equipment adequately:

5.1.1 ASTM designation and year of issue,

5.1.2 Valve type (see 4.1.1),

5.1.3 Valve style (see 4.1.2),

5.1.4 Valve size (see 4.1.3),

5.1.5 Valve pressure rating (see 4.1.4),

5.1.6 End connections (see 4.1.5),

5.1.7 Valve inlet operating pressure,

5.1.8 Set point (see 3.1.7 and 7.2),

5.1.9 Tamper-proof set point adjustment, if required (see 6.3.2),

5.1.10 Supplementary requirements, if any (see S1 through S4), and

5.1.11 Maximum vibration frequency and displacement amplitude, if other than specified (see S1.2).

6. Valve Construction

6.1 Valves shall incorporate the features specified in 6.2-6.16.

6.2 Materials of Construction—Material requirements for the automatic shut-off valve shall be as follows: The pressure-containing envelope shall be 300 series corrosion-resistant steel (304, 304L, 316, or 316L). Internal parts including springs, poppets, retainers, etc. shall be 300 series corrosion-resistant steel, nickel-aluminum-bronze, nickel-copper (70-30), or bronze. Other materials for both the pressure-containing envelope and internal parts may be selected to assure compatibility with the line medium, weldability, and to provide corrosion resistance without requiring painting, coating, or plating. Materials for contacting parts shall be selected to minimize electrolytic corrosion and galling.

6.3 General Requirements:

6.3.1 Automatic shut-off valves shall be self-contained, requiring no external power source for operation. The automatic shut-off valve shall be capable of meeting all requirements of this specification and provide extended reliable operation.

6.3.2 Automatic shut-off valves shall incorporate a provision for manually resetting. This shall constitute an isolatable bleed-by which is operable with the valve in the pipeline under pressure and which functions by equalizing pressure across the poppet. Style 1 valves shall in addition, incorporate a provision which automatically resets the valve, and which constitutes a small non-isolatable bleed-by.

6.4 Threads—Threads shall be as specified in ANSI B1.1. Where necessary, provisions shall be incorporated to prevent the accidental loosening of threaded parts. The design shall be such that standard wrenches can be used on all external bolting. Lock-wire shall not be used. Any exposed threads shall be protected by plastic caps for shipping.
6.5 Interchangeability—The automatic shut-off valve, including all associated piece parts, shall have part number identity, and shall be replaceable from stock or the manufacturer on a nonselective and random basis. Parts having the same manufacturer’s part number shall be directly interchangeable with each other with regard to installation (physical) and performance (functional). Physically interchangeable assemblies, components, and parts are those which are capable of being readily installed, removed or replaced without alteration, misalignment, or damage to parts being installed or to adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.6 Nonmetallic Element Interchangeability—Nonmetallic elements, including but not limited to, seat rings, poppet seat inserts, cushions, and O-rings shall be treated as separately identified and readily replaceable parts.

6.7 Maintainability—Maintenance shall require standard tools to the maximum extent possible. Any special tools required for maintenance shall be identified, and shall be supplied as part of the valve.

6.8 Reversibility—Seating inserts, if applicable, shall not be physically reversible unless they are also functionally reversible to preclude incorrect assembly.

6.9 Adjustments—There shall be no adjustments required in the automatic shut-off valve during or after assembly other than the set point.

6.10 Pressure Envelope—The valve shall be designed to pass a hydrostatic shell test at a pressure of at least 1.5 times the 100°F (38°C) pressure rating of the valve without damage.

6.11 Body Construction—All pressure lines, including the reset bleed line, shall be internally ported. The bonnet and bottom cap (where applicable) shall be attached to the body by bolting, threading, or threaded-union connections.

6.12 Set-Point Adjustment—Set point shall be adjustable through the range specified in 7.4. Type I valves shall be adjustable with the valve in the line under pressure. Type II valves may be removed from the line for adjustment. The set point shall incorporate right-hand threads so that a clockwise rotation increases the set point. Means shall be used to prevent an accidental or inadvertent change in set point. The option of a tamper-proof set-point adjustment (lead seal, and so forth) shall be available and shall be specified as in Section 5.

6.13 Port Configuration—The automatic shut-off valve shall have in-line inlet and outlet ports.

6.14 Springs—Spring incorporated in the automatic shut-off valve shall not be compressed solid during operation. Spring ends shall be squared and ground. Engagement or disengagement of parts against spring compression shall not be permitted.

6.15 Guiding—The valve poppet shall be guided to prevent binding or seizing, and to ensure proper seating under all operating conditions. Proper alignment of all internal operating parts shall be maintained with interchangeable parts and under all tolerance stack-up conditions.

6.16 Accessibility—Type I automatic shut-off valve shall be accessible for adjustment or service, without removing the automatic shut-off valve from the line.

7. Performance Requirements

7.1 Automatic shut-off valves shall meet the requirements of 7.2-7.8.

7.2 Set Point—The required set point as defined in 3.1.7, shall be as specified (see Section 5).

7.3 Set-Point Accuracy—The set-point accuracy, as defined in 3.1.8, shall be plus or minus 10 % of the set point.

7.4 Range of Set-Point Adjustment—Automatic shut-off valves shall be capable of meeting all performance requirements when set at any point within plus or minus 25 % of the nominal specified set point.

7.5 Trip Differential Pressure—The pressure differential at which the automatic shut-off valve trips shut shall not exceed the values specified in Table 2.

7.6 Reset Pressure—Once shut, the automatic shut-off valve shall remain shut until the pressure across the valve is equalized.

7.7 Seat Tightness—Once shut, and with the manually operated isolatable bleed-by closed, the automatic shut-off valve shall meet the following seat tightness requirements. Where necessary, leakage measurement shall start after temperature stabilization.

7.7.1 Style I Valves—Flow leakage shall be less than 2 % and no greater than 5 % of the set-point flow.

7.7.2 Style 2 Valves—Flow leakage shall not exceed 60 standard cubic inches per hour (SCIH), per inch of valve size.

7.8 External Leakage—The automatic shut-off valve external leakage shall be bubble-tight at its operating pressure conditions over a 3-min period.

8. Tests Required

8.1 Each automatic shut-off valve must pass the tests outlined in 8.2-8.6.

8.2 Visual Examination—The automatic shut-off valve shall be examined visually to determine conformance with the ordering data, interface dimensions, and workmanship without disassembly.

8.3 Hydrostatic Shell Test—The automatic shut-off valve shall be hydrostatically tested using water by applying a test pressure equal to the 1.5 times the 100°F (38°C) pressure rating to the valve inlet and outlet to check its structural integrity. Pressure shall be applied for three minutes. Air or nitrogen may be used in lieu of water, providing appropriate safety precautions are taken to minimize the risk associated with the use of a compressible fluid. There shall be no external leakage, permanent distortion, or structural failure.

8.4 Seal Tightness Test (Style 2 Valves Only)—The automatic shut-off valve shall be tested with air or nitrogen gas with an inlet test pressure equal to the 1.1 times the 100°F (38°C) pressure rating. The leakage requirements of 7.7 shall be met.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Maximum Allowable Trip Differential Pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Inlet Operating Pressure, psi (MPa)</td>
<td>Maximum Allowable Trip Differential Pressure, psi (kPa)</td>
</tr>
<tr>
<td>400 (2.758)</td>
<td>15 (103)</td>
</tr>
<tr>
<td>1500 (10.342)</td>
<td>40 (276)</td>
</tr>
<tr>
<td>3000 (20.684)</td>
<td>60 (414)</td>
</tr>
<tr>
<td>6000 (41.369)</td>
<td>75 (517)</td>
</tr>
</tbody>
</table>
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements S1, S2, S3, or S4 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Supplemental Tests

S1.1 Supplemental tests shall be conducted at a laboratory satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.2 through S1.5.

S1.2 Shock Test—The automatic shut-off valve shall be subjected to and meet the high-impact shock tests for grade A, class I as specified in MIL-S-901 pressurized with water, air, or nitrogen. The inlet port shall be pressurized to the maximum operating pressure. There shall be no structural damage to the automatic shut-off valve. There shall be no degradation to the performance capability of the automatic shut-off valve. Tripping shut of the automatic shut-off valve is permissible.

S1.3 Vibration Test—The automatic shut-off valve shall be vibration tested in accordance with type I of MIL-STD-167-1 pressurized with water, air, or nitrogen. The inlet port shall be pressurized to the maximum inlet operating pressure. At frequencies up to and including 33 Hz (unless otherwise specified in the ordering information, Section 5), there shall be no resonance in the range of frequencies tested. There shall be no structural damage or degradation to the performance capability of the automatic shut-off valve.

S1.4 Noise Test—The automatic shut-off valve shall be tested for airborne noise in accordance with MIL-STD-740-1. The noise (sound pressure level) shall not exceed 85 db observed at one-metre distance from the automatic shut-off valve.

S1.5 Posttest Examination—The automatic shut-off valve shall be disassembled and examined for any evidence of excessive wear, degradation, or impending damage or breakage.

S2. Technical Data and Certification Requirements

S2.1 Drawings—Assembly drawings or catalog sheets of the automatic shut-off valve which clearly depict design shall be provided. The following information shall also be included as part of the drawings or catalog sheets:

S2.1.1 Bill of material listing specification, grade, condition, and any other data required to fully identify the properties of the materials proposed. This shall include identifications, material and size designations, shore hardness, and any other data necessary to fully identify the parts.

S2.1.2 In cases where standard commercial or military parts are or can be employed, these shall be appropriately identified.
S2.1.3 Outline dimensions, disassembly space, location, and size of end connections.
S2.1.4 Estimated weight and center of gravity (vertical, longitudinal, and transverse).
S2.1.5 Recommended assembly torques or equivalent procedures for making up all joints and threaded assemblies.
S2.1.6 The following performance information shall be included:
S2.1.6.1 Set point and adjustable range.
S2.1.6.2 Specified operating conditions.
S2.2 Technical Manuals—Technical manuals shall provide a description, installation procedures, operation and maintenance instructions, and illustrated parts breakdown for the automatic shut-off valve, organized as follows:
S2.2.1 Chapter 1—General Information and Safety Precautions.
S2.2.2 Chapter 2—Operation.
S2.2.3 Chapter 3—Functional Description.
S2.2.4 Chapter 4—Scheduled Maintenance.
S2.2.5 Chapter 5—Troubleshooting.
S2.2.6 Chapter 6—Corrective Maintenance.
S2.2.7 Chapter 7—Parts List.
S2.2.8 Chapter 8—Installation.
S2.2.9 In addition, the following shall be included as part of the technical manual content:
S2.2.9.1 The assembly drawings for the automatic shut-off valve, supplemented by additional illustrations where necessary to adequately illustrate operation and maintenance. These additional illustrations may consist of blowouts, partial or full sections, and may eliminate extraneous lines and details to clarify the interaction of parts.
S2.2.9.2 Table listing wrench sizes and assembly torques (or other equivalent procedures) for making up all joints and threaded assemblies.
S2.2.9.3 Detailed disassembly and reassembly procedures. In addition to a section providing procedures for the complete disassembly and reassembly of the automatic shut-off valve, maintenance and troubleshooting sections shall contain, or refer to, only the limited disassembly and reassembly required to accomplish each particular operation. This is intended to reduce the possibility of unnecessary disassembly and unnecessary disturbance of adjustments when performing specific or limited maintenance or troubleshooting operations.
S2.2.9.4 Adjustment procedures for the automatic shut-off valve.

S3. Quality Assurance

S3.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.
S3.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.
S3.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.
S3.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.
S3.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.
S3.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.
S3.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system that identified inspection status of material throughout all stages of manufacture.
S3.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions utilizing documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.
S3.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.
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S3.11 Nondestructive Examination—Provisions shall be made to utilize non-destructive examination, as necessary, to ensure that material and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer and/or qualified by a recognized national body, and their authorizations/qualification records shall be made available to the inspection authority if required.
S3.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.
S3.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.
X1. GUIDELINES FOR SELECTION OF AUTOMATIC SHUT-OFF VALVES

X1.1 Scope—This appendix provides general guidelines for the selection of automatic shut-off valves, and therefore, its use does not in any way relieve the user of the final responsibility in the selection and installation of automatic shut-off valves.

X1.2 The automatic shut-off valves described by this specification are intended to be installed as safety devices in air or nitrogen service to quickly and automatically shut off flow under certain excess flow conditions caused by a downstream failure, such as a hose rupture. They are designed to respond only to the pressure differential across the automatic shut-off valve created by the flow. Therefore, these valves are not intended primarily to preserve the upstream fluid from causes such as a slow downstream leak.

X1.2.1 In the open position and under no flow conditions, the valve is fully balanced with no net pressure force tending to open or close the valve. The valve is actuated to close when the pressure drop across the valve caused by a flow exceeds a set valve. The valve is set by adjusting the distance between the poppet and the seat in the open position (that is, changing the restriction to flow presented by the valve) and thereby changing the flow-pressure conditions under which the set pressure drop occurs. Once shut, the valve remains shut until the static pressure drop across the valve is reduced.

X1.3 To function as intended, the characteristics of the system and the location of the automatic shut-off valve must be such that the lowest pressure drop created across the automatic shut-off valve as the result of a casualty will always be greater than the highest pressure drop created across the valve during any normal operating condition. The separation between these two points must be sufficient to be compatible with the accuracy of the automatic shut-off valve selected. If there is not a sufficient separation, or if these points overlap, then either the automatic shut-off valve will inadvertently trip shut during certain normal operating situations, or it will fail to trip shut under certain casualty situations, or both, and therefore, its successful application will not be possible.

X1.4 Since the automatic shut-off valve is statically pressure balanced, the set point at which it would trip shut is established by the spring preload tending to hold the poppet in the open position combined with the flow restriction presented by the valve when in the open position.

X1.5 Type I automatic shut-off valves are intended to provide maximum maintainability (particularly in systems where removal and reinstallation of the valve body from the pipe-line may be difficult because of pipe spring) by permitting valve adjustment and removal of all valve internals with the valve in the pipe-line. Type II automatic shut-off valves require removal of the valve from the pipe-line for adjustment or repair and are intended for applications where compactness and light-weight are the primary considerations.
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Standard Specification for
Hand-Operated, Globe-Style Valves for Gas (Except Oxygen Gas) and Hydraulic Systems

1. Scope

1.1 This specification covers the design, construction, testing, and operating requirements for hand-operated, quick-change cartridge trim, in-line body and angle-body, globe-style valves for use in gas (except oxygen gas) and hydraulic systems. These valves may be used for on-off, and/or throttling applications.

1.2 The values stated in this specification in inch-pound units are to be regarded as the standard. The SI equivalents shown in parenthesis are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
F 992 Specification for Valve Label Plates
2.2 American National Standards Institute (ANSI):
B1.1 Unified Screw Threads (UN and UNR Thread Form)
B1.20.1 Pipe Threads, General Purpose (Inch)
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.25 Butt Welding Ends
B16.34 Valves—Flanged, Threaded, and Welded End
2.3 Military Standards and Specifications:
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-740-1 Airborne Noise Measurements and Acceptance Criteria of Shipboard Equipment
MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for

MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver-Brazing, General Specification for
2.4 Government Drawings:
Naval Sea Systems Command (NAVSEA):
NAVSEA 803-1385884 Unions, Fittings and Adapters Butt and Socket Welding 6000 PSI, WOG, NPS
NAVSEA 803-1385943 Unions, Silver Brazing 3000 PSI, WOG, NPS, for UT Inspection
NAVSEA 803-1385946 Unions, Bronze Silver Brazing, WOG for UT Inspection

3. Terminology

3.1 Definitions:
3.1.1 bubble-tight—no visible leakage over a 3-min period using either water submersion or the application of bubble fluid for detection.
3.1.2 external leakage—leakage from the valve that escapes to atmosphere.
3.1.3 flow capacity—the ability of a valve to pass flow under any given set of pressure conditions. The flow capacity of a valve is directly related to its Flow Coefficient (Cv). The Flow coefficient is the quantity of water passing through a valve, expressed in gallons/minute (litres/minute), when 1 psi (6.895 kPa) pressure drop at 60°F (16°C) is applied across the valve.
3.1.4 globe-style valves—a basic control valve type that gets its name from the globular shape of its body with an internal bridgewidth construction. It normally uses a basic rising stem/plug for the closure member.
3.1.5 hydrostatic shell test pressures—the hydrostatic test pressures that the valve is required to withstand without damage. Valve operation is not required during application of shell test pressure, but the valve must meet all performance requirements after the shell test pressure has been removed.
3.1.6 internal leakage—leakage from higher pressure to lower pressure portions of the valve.
3.1.7 operating pressures—the pressures within the valve during service.
3.1.8 pressure ratings—the pressure ratings of the valve shall be as defined in the documents listed in Table 1. The pressure ratings (also called pressure-temperature ratings)

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.
2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.
4 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
establish the maximum allowable working (service) pressures of a component (valve, end connections, and so forth) at various temperatures.

3.1.9 quick-change cartridge trim—a construction that facilitates rapid and reliable seat-ring/seat removal and replacement by retaining the seat-ring/seat in the valve cartridge, as opposed to a seat-ring which is threaded, welded, brazed, or made integral with the valve body.

3.1.10 seat tightness—the ability of a valve to prevent internal leakage from the valve-inlet to the valve-outlet.

4. Classification

4.1 Valves shall be of the following types, styles, sizes, pressure ratings, and end connections, as specified in Section 5.

4.1.1 Types—Valves shall have either Type I (angle body construction) or Type II (inline body construction).

4.1.2 Styles—Valves shall be either Style I (shut-off valves) or Style 2 (throttling valves).

4.1.3 Sizes—Valve sizes shall be 1/8 NPS (10.2 mm), 1/4 NPS (13.5 mm), 5/8 NPS (17.2 mm), 1/2 NPS (21.3 mm), 3/4 NPS (26.9 mm), 1 NPS (33.7 mm), 1 1/4 NPS (42.4 mm), 1 1/2 NPS (48.3 mm), and 2 NPS (60.3 mm).

4.1.4 Pressure Ratings—Valves shall have a pressure rating selected from those listed in Table 1 and specified in Section 5. The inlet and outlet pressure ratings of the valve shall be identical for any given valve.

4.1.5 End Connections—Valves shall have end connections selected from those listed in Table 1 and specified in Section 5. The inlet and outlet end connections of the valve shall be identical for any given valve.

5. Ordering Information

5.1 Ordering documentation for valves under this specification shall include the following information, as required to describe the equipment adequately.

5.1.1 ASTM designation and year of issue.

5.1.2 Valve type (see 4.1.1).

5.1.3 Valve style (see 4.1.2).

5.1.4 Valve size (see 4.1.3).

5.1.5 Valve pressure rating (see 4.1.4).

5.1.6 Valve end connections (see 4.1.5).

5.1.7 Line medium.

5.1.8 Temperature of line medium.

5.1.9 Supplementary requirements, if any (see S1 through S4).

5.1.10 Maximum vibration frequency and displacement amplitude, if other than specified (see S1.4), and

5.1.11 Maximum permissible noise level, if other than specified (see S1.5).

6. Valve Construction

6.1 Valves shall incorporate the design features specified in 6.1.1-6.1.17.

6.1.1 General Requirements:

6.1.1.1 Valves furnished under this specification shall be soft-seated, globe-style valves using a cartridge in which all working parts including the seat are removable as an assembly.

6.1.2 Materials of Construction—Material requirements for these valves shall be as follows: The pressure containing envelope shall be 300 series corrosion-resistant steel, nickel-copper (70-30), nickel-aluminum-bronze, or bronze. Internal parts in contact with the line media shall be 300 series corrosion-resistant steel, nickel-copper (70-30), copper-nickel (70-30), bronze, nickel-aluminum-bronze, or naval brass. Other materials not listed above may be selected to assure compatibility with the line medium, weldability, and to provide corrosion resistance without requiring painting, coating, or plating. Materials for contacting parts shall be selected to minimize electrolytic corrosion and galling.

6.1.3 Soft-Seating Insert—A soft-seating (non-metallic) insert, if applicable, shall be field replaceable and incorporated in the valve plug. Soft-seating inserts shall be protected from direct flow impingement, excessive loading and extrusion, or any other effect jeopardizing their useful life. Soft-seating inserts shall be of the simplest practical configuration to facilitate emergency replacement manufacture where necessary.

6.1.4 Pressure Envelope—The valve shall be designed to pass a hydrostatic shell test at a pressure of at least 1.5 times the 100°F (38°C) pressure rating of the valve without any damage.

6.1.5 Threads—Threads shall be as specified in ANSI B1.1. Where necessary, provisions shall be incorporated to prevent the accidental loosening of threaded parts. The design shall be such that standard wrenches can be used on all external bolting. Lock-wire shall not be used. Any exposed threads shall be protected by plastic caps for shipping.

6.1.6 Accessibility—All internal parts of the valve shall be accessible for adjustment or service, without removing the valve body from the line.

6.1.7 Interchangeability—The valve, including all associated piece parts, shall have part number identity, and shall be replaceable from stock or the manufacturer on a nonselective and random basis. Parts having the same manufacturer’s part number shall be directly interchangeable with each other with respect to installation (physical) and performance (function).
Physically interchangeable assemblies, components, and parts are those which are capable of being readily installed, removed, or replaced without alteration, misalignment, or damage to parts being installed or to adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.1.8 Nonmetallic Element Interchangeability—Nonmetallic elements, including but not limited to, seat rings, soft-seating inserts, cushions, and O-rings shall be treated as separately identified and readily replaceable parts.

6.1.9 Maintainability—Valve maintenance shall require standard tools to the maximum extent possible. Any special tools required for maintenance shall be identified, and shall be supplied with the valve.

6.1.10 Reversibility—Seat inserts shall not be physically reversible unless they are also functionally reversible to preclude incorrect assembly.

6.1.11 Adjustments—There shall be no adjustments required in the valve during or after assembly.

6.1.12 Bidirectional Operation and Bubbletight Shut-Off—The valve shall be capable of operation and bubbletight shut-off with a differential pressure equal to the rated pressure applied across the valve in either direction of flow.

6.1.13 Guiding—The valve poppet shall be guided to prevent binding or seizing, and to ensure proper seating, under all operating conditions. Proper alignment of all internal operating parts shall be maintained with interchangeable parts and under all tolerance stack-up conditions.

6.1.14 Valve Operating Force—The maximum permissible total tangential force required on the handwheel/handle for operating or seating/unseating the valve shall not exceed 50 lb (222 N), when the valve is subjected to a differential pressure equal to the rated pressure applied across the valve in either direction of flow.

6.1.15 Pressurization Rate—To prevent the possibility of auto-ignition, the valve shall be capable of being operated to limit the rate of downstream pressure buildup in a depressurized volume (with the rated pressure upstream) to 200 psi (1380 kPa) per second. Downstream volumes for this pressurization rate shall be taken as 10 pipe diameters.

6.1.16 Operation—The valve shall close by a clockwise rotation of handwheel/handle when viewed from directly over the handwheel/handle.

6.1.17 Envelope Dimensions—For union-end valves only, the overall envelope dimensions shall be as shown in Fig. 1 (angle body construction) or Fig. 2 (inline body construction), as applicable, and Table 2.

7. Performance

7.1 Valves shall meet the performance requirements of 7.1.1-7.1.3.

7.1.1 Flow Capacity—The flow capacity of the valve, expressed in terms of $C_v$, shall be equal or greater than the values shown in Table 3.

7.1.2 Seat Tightness—Valve shall be bubbletight at 1.1 times the 100°F (38°C) pressure rating in both directions when closed with a handwheel/handle force not exceeding that specified in 6.1.14 (or the manufacturer’s published recommendations, when less).

7.1.3 External Leakage—Valve external leakage shall be bubbletight at its 100°F (38°C) pressure rating.

8. Tests Required

8.1 Each valve shall pass the tests outlined in 8.1.1-8.1.4.

8.1.1 Visual Examination—The valve shall be examined visually to determine conformance with the ordering data and workmanship without disassembly.

8.1.2 Hydrostatic Shell Test—The valve shall be hydrostatically tested with water by applying test pressures equal to 1.5 times the 100°F (38°C) pressure rating to the inlet and outlet ports (with the valve in the open position) to check the
structural integrity of the valve. Pressure shall be applied for three minutes. Air or nitrogen may be used in lieu of water, providing appropriate safety precautions are taken to minimize the risk associated with the use of a compressible fluid. There shall be no external leakage, permanent distortion, or structural failure.

8.1.3 Seat Tightness Test—The valve shall be seated with an applied handwheel/handle force not exceeding that specified in 6.1.14 (or the manufacturer’s published recommendations, when less). Air or nitrogen at 1.1 times the 100°F (38°C) pressure rating of the valve shall be used for seat tightness test, using bubble fluid or immersing the outlet, or a line from the outlet, under water. The valve shall show no visible evidence of leakage over a 3-min period. The valve shall be tested in both directions of flow to assure bidirectional seat tightness. For valves used for helium or helium mixture service, the testing medium shall be helium or helium/nitrogen mixture.

8.1.4 External Leakage Test—With the valve in the partially open position, air or nitrogen shall be applied at a test pressure equal to the 100°F (38°C) pressure rating of the valve to the inlet port, and the outlet port blanked off. External leakage shall be checked using bubble fluid, or by submerging the valve in water. There shall be no visible external leakage over a 3-min period. For valves used for helium or helium mixture service, the testing medium shall be helium or helium/nitrogen mixture.

9. Marking

9.1 Identification Plate—An identification plate of corrosion-resistant metal in accordance with Specification F 992; Types I, II, III, or IV shall be permanently attached to the valve and shall include the following information (some or all information may instead be stamped, etched, or cast on the valve body):

9.1.1 Manufacturer’s name,
9.1.2 ASTM designation and year of issue,
9.1.3 Manufacturer’s model/part number,
9.1.4 Size, and
9.1.5 Pressure rating.

9.2 Body Markings—Valve body shall be marked per ANSI B16.34.

10. Quality Assurance System

10.1 The manufacturer shall establish and maintain a quality assurance system that will ensure all the requirements of this specification are satisfied. This system shall also ensure that all valves will perform in a similar manner to those representative valves subjected to original testing for determination of the operating and flow characteristics.

10.2 A written description of the quality assurance system the manufacturer will use shall be available for review and acceptance by the inspection authority.

10.3 The purchaser reserves the right to witness the production tests and inspect the valves in the manufacturer’s plant to the extent specified on the purchase order.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements S1, S2, S3, or S4 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.
S1. Supplemental Tests

S1.1 Supplemental tests shall be conducted at a laboratory satisfactory to the customer and shall consist of the examination and tests selected from those specified in S1.1.1 through S1.1.6.

S1.1.1 Operational Test—The valve shall be attached to an air or nitrogen source at the rated pressure with flow through the valve over the seat. A needle valve shall be installed downstream to limit flow during cycling tests. The valve shall be cycled as follows:

(a) Cycle 50 times and then seat valve with the maximum seating force as specified per manufacturer’s recommended published data. One cycle shall consist of one complete opening and closing.

(b) Allow valve to remain pressurized for 1 h in the seated condition.

(c) Repeat (a) and (b) above until valve has undergone 2500 cycles.

(d) After each 50 cycles, stem and seat leakage shall be checked.

(e) Seating, unseating, and running torques shall be noted during this test. Maximum valves should be within those listed in manufacturer’s published data.

No lubrication shall be applied to the stem seal either before or during these tests.

S1.1.2 Pressurization Rate Test—With a test pressure equal to the 100°F (38°C) pressure rating applied upstream, and a depressurized downstream volume as specified in 6.1.15, the valve shall be operated to demonstrate its ability to meet the pressurization rate specified in 6.1.15.

S1.1.3 Shock Test—The valve shall be subjected to and meet the high-impact shock tests for Grade A, Class I as specified in MIL-S-901, pressurized with water, air, or nitrogen. The valve inlet shall be pressurized to a test pressure of the 100°F (38°C) pressure rating. There shall be no structural damage to the valve. There shall be no degradation to the performance capability of the valve.

S1.1.4 Vibration Test—The valve shall be vibration tested in accordance with Type I of MIL-STD-167-1 pressurized with air or nitrogen. The valve inlet shall be pressurized to the 100°F (38°C) pressure rating. At frequencies up to and including 33 Hz (unless otherwise specified in the ordering information, Section 5), there shall be no resonance in the range of frequency tested. There shall be no structural damage or degradation to the performance capability of the valve.

S1.1.5 Noise Test—The valve shall be tested for airborne noise in accordance with MIL-STD-740-1. The noise (sound pressure level) shall not exceed 85 db, unless otherwise specified in 5.0, observed at one-metre distance from the valve.

S1.1.6 Post-Test Examination—After completion of each or all of the tests specified in S1.1.1 through S1.1.5, the valve shall be disassembled and examined for any evidence of excessive wear, degradation, or impending damage or breakage.

S2. Technical Data Requirements

S2.1 Drawings—Assembly drawings or catalog sheets of the valve which clearly depict design shall be provided. The following information shall also be included as part of the drawings or catalog sheets:

S2.1.1 Bill of material listing specification, grade, condition, and any other data required to fully identify the properties of the materials proposed. This shall include identifications, material and size designations, shore hardness, and any other data necessary to fully identify the parts.

S2.1.2 In cases in which standard commercial or military parts are or can be used, these shall be appropriately identified.

S2.1.3 Outline dimensions, disassembly space, location, and size of end connections.

S2.1.4 Estimated weight and center of gravity (vertical, longitudinal, and transverse).

S2.1.5 Recommended assembly torques or equivalent procedures for making up all joints and threaded assemblies.

S2.2 Technical Manuals—Technical manuals shall provide a description, installation procedures, operation and maintenance instructions, and illustrated parts breakdown for the valve, organized as follows:

S2.2.1 Chapter 1—General Information and Safety Precautions.

S2.2.2 Chapter 2—Operation.

S2.2.3 Chapter 3—Functional Description.

S2.2.4 Chapter 4—Scheduled Maintenance.

S2.2.5 Chapter 5—Troubleshooting.

S2.2.6 Chapter 6—Corrective Maintenance.

S2.2.7 Chapter 7—Parts List.

S2.2.8 Chapter 8—Installation.

S2.3 In addition, the following shall be included as part of the technical manual content:

S2.3.1 The assembly drawings for the valve, supplemented by additional illustrations where necessary to adequately illustrate operation and maintenance. These additional illustrations may consist of blowouts, partial or full sections, and may eliminate extraneous lines and details to clarify the interaction of parts.

S2.3.2 Table listing wrench sizes and assembly torques (or other equivalent procedures) for making up all joints and threaded assemblies.

S2.3.3 Detailed disassembly and reassembly procedures. In addition to a section providing procedures for the complete disassembly and reassembly of the valve, maintenance, and troubleshooting sections shall contain, or refer to, only the limited disassembly and reassembly required to accomplish each particular operation. This is intended to reduce the possibility of unnecessary disassembly and unnecessary disturbance of adjustments when performing specific or limited maintenance or troubleshooting operations.

S3. Quality Assurance

S3.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.

S3.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.

S3.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection, and quality assurance instructions, and illustrated parts breakdown for the valve.
control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

S3.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.

S3.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications, and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.

S3.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.

S3.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system which identified inspection status of material throughout all stages of manufacture.

S3.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions utilizing documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.

S3.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examinations and inspections.

S3.10 Welding—The quality control system shall include provisions for ensuring that welding conforms to specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made available to the inspection authority if required.

S3.11 Nondestructive Examination—Provisions shall be made to utilize non-destructive examination, as necessary, to ensure that material and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer and/or qualified by a recognized national body, and their authorizations/qualification records shall be made available to the inspection authority if required.

S3.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.

S3.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatments have been applied. Means should be provided by which heat treatment requirements can be verified.

S3.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of material during all stages of manufacture and shall be able to distinguish between inspected and noninspected material.

S3.15 Calibration of Measurement and Test Equipment—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring, and test equipment to be used in verifying conformance to the specified requirements. Such calibration shall be traceable to a national standard and calibration records shall be maintained.

S3.16 Records Maintenance—The manufacturer shall have a system for the maintenance of inspection records, radiographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S3.17 Sample Forms—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S3.18 Inspection Authority—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with originals or copies of such documents.

S4. Special Material, Design, and Performance Considerations

S4.1 Recovered Materials—Unless otherwise specified in this specification, all equipment, material, and articles incorporated in the products covered by this specification shall be new and may be fabricated using materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term “recovered materials” means materials that have been collected or recovered from solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or rebuilt products is allowed under this specification unless otherwise specifically specified.

S4.2 Pipe threads shall not be used in the construction of the valve.
Standard Specification for Pressure-Reducing Valves for Air or Nitrogen Systems

This standard is issued under the fixed designation F 1795; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, construction, testing, and operating requirements for self-contained pressure-reducing valves for air or nitrogen systems.

1.2 The values stated in this specification in inch-pounds units are to be regarded as the standard. The SI equivalent shown in parentheses are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
F 992 Specification for Valve Label Plates
F 1685 Pressure-Reducing Manifolds for Air or Nitrogen Systems

2.2 American National Standards Institute (ANSI):
B1.1 United Screw Threads (UN and UNR Thread Form)
B1.20.1 Pipe Threads, General Purpose (Inch)
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.25 Butt welding Ends
B16.34 Valves—Flanged, Threaded, and Welded End

2.3 Military Standards and Specifications:
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-740-1 Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment
MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver Brazing, General Specifications for

2.4 Government Drawings:
Naval Sea Systems Command (NAVSEA):

NAVSEA 803-1385884 Unions, Fittings and Adapters Butt and Socket Welding 6000 PSI, WOG, NPS
NAVSEA 803-1385943 Unions, Silver Brazing 3000 PSI, WOG, NPS, for UT Inspection
NAVSEA 803-1385946 Unions, Bronze Silver Brazing, WOG for UT Inspection

3. Terminology

3.1 Definitions:
3.1.1 accuracy of regulation—the amount by which the downstream pressure may vary when the pressure-reducing valve is set at any pressure within the required set pressure range and is subjected to any combination of inlet pressure, flow demand, and ambient temperature variations within the specified limits.
3.1.2 bubble-sight—no visible leakage over a 3-min period using either water submersion or the application of bubble fluid for detection.
3.1.3 external leakage—leakage from the pressure-reducing valve which escapes to atmosphere.
3.1.4 fail-open flow capacity—the ability of the pressure-reducing valve to pass flow under any given set of pressure conditions when, as a result of mechanical failure, it has assumed a position of least resistance to flow.
3.1.5 flow capacity—the ability of the pressure-reducing valve to pass flow under any given set of pressure conditions.
3.1.6 flow rate demand—the amount of flow demanded by the system at any given time downstream of the pressure-reducing valve.
3.1.7 flow rate demand range—the range over which the flow demand can vary.
3.1.8 hydrostatic shell test pressure(s)—The hydrostatic test pressures that the inlet and outlet of the pressure-reducing valve is required to withstand without damage. Pressure-reducing valve operation is not required during application of shell test pressure, but the pressure-reducing valve must meet all performance requirements after the shell test pressure has been removed.
3.1.9 inlet operating pressure range—the range over which the inlet pressure supplied to the pressure-reducing valve can vary under any operational conditions which the pressure-reducing valve can be subjected to in service.
3.1.10 operating pressure(s)—the pressures within the pressure-reducing valve during service.

3.1.11 pressure ratings—the pressure ratings of the pressure-reducing valve shall be as defined in the documents listed in Table 1. The pressure ratings (also called pressure-temperature ratings) establish the maximum allowable working (service) pressures of a component (valve, end connections, and so forth) at various temperatures. For a pressure-reducing valve, the pressure ratings may not be identical for the valve inlet and outlet.

3.1.12 pressure-reducing valve—a component which accomplishes automatic regulation of the downstream pressure. In this component, the upstream pressure is reduced to the desired downstream pressure.

3.1.13 pressure reversal—a condition in which pressure exists at the outlet of a pressure-reducing valve when the loading element is deactivated (set spring adjustment backed off fully or dome charge vented off completely) and inlet pressure is vented off.

3.1.14 seat-tightness—the ability of the pressure-reducing valve to prevent leakage from the valve inlet to the valve outlet.

3.1.15 self-contained pressure-reducing valve—a pressure-reducing valve that does not use an external power source, such as compressed air, electricity, or hydraulic fluid for operation, but instead uses the line fluid for operation.

3.1.16 set pressure—the outlet pressure delivered by the pressure-reducing valve at the time the pressure setting is made. For the purposes of this specification, it will be assumed that the setting is made when there is no flow demand on the pressure-reducing valve (“lock-up” condition), and the pressure-reducing valve is at surrounding ambient temperature.

3.1.17 set pressure range—the range of set pressures (set pressure limits) over which the pressure-reducing valve can be adjusted while meeting the performance requirements specified.

3.1.18 soft-seating insert—the insert, incorporated in either the poppet or the seat of the pressure-reducing valve, which ensures bubble-tight seat tightness under all operating conditions.

3.1.19 valve poppet—the part of the pressure-reducing valve trim which established a rate of flow by moving toward or away from the valve seat.

4. Classification

4.1 Pressure-reducing valves shall be of the following types, sizes, pressure ratings, and end connections, as specified in Section 5.

4.1.1 Types—Pressure-reducing valves shall be either Type I (inlet outlet end connections of the same pressure rating) or Type II (outlet end connection pressure rating lower than the inlet end connection rating) and specified in Section 5.

4.1.2 Sizes—Pressure-reducing valve sizes shall be 1/8 NPS (10.2 mm), 1/4 NPS (13.5 mm), 1/8 NPS (17.2 mm), 1/2 NPS (21.3 mm), 3/4 NPS (26.9 mm), 1 NPS (33.7 mm), 1 1/4 NPS (42.4 mm), 1 1/2 NPS (48.3 mm), and 2 NPS (60.3 mm).

4.1.3 Pressure Ratings—Pressure-reducing valves shall have pressure rating(s) selected (see 3.1) from Table 1. The pressure rating(s) selected shall be specified in Section 5.

4.1.4 End Connections—Pressure-reducing valves shall have end connections selected from those listed in Table 1 and specified in Section 5.

5. Ordering Information

5.1 Ordering documentation for pressure-reducing valves under this specification shall include the following information as required to describe the equipment adequately.

5.1.1 ASTM designation and year of issue,
5.1.2 Valve type (see 4.1.1),
5.1.3 Valve inlet and outlet sizes (see 4.1.2),
5.1.4 Pressure rating(s) (see 4.1.3),
5.1.5 Type of end connections (see 4.1.4),
5.1.6 Inlet operating pressure range.
5.1.7 Set pressure and set pressure range, if other than specified (see 7.1.3).
5.1.8 Flow rate demand range (see 7.1.1, S1.1.2).
5.1.9 Accuracy of regulation required, if set pressure is below 10 psig (see 7.1.2).
5.1.10 Tamper-proof set-point adjustment, if required (see 6.1.9).
5.1.11 Supplementary requirements, if any (S1 through S4).
5.1.12 Maximum vibration frequency and displacement amplitude, if other than specified (see S1.1.4).

6. Valve Construction

6.1 Valves shall incorporate the design features specified in 6.1.1-6.1.19.

6.1.1 General Requirements—Pressure-reducing valves shall be self-contained, requiring no external power source for operation. The pressure-reducing valve shall be capable of

### Table 1: Pressure Ratings for Pressure-Reducing Valve

<table>
<thead>
<tr>
<th>Type of End Connection</th>
<th>Pressure Rating</th>
<th>Applicable Documents for Dimensional Details of End Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt-welded</td>
<td>ANSI B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ANSI B16.25</td>
</tr>
<tr>
<td>Socket-welded</td>
<td>ANSI B16.34 Class 150, 300, 400, 600, 900, 1500, 2500, or 4500</td>
<td>ANSI B16.11</td>
</tr>
<tr>
<td>Threaded (tapered pipe thread)</td>
<td>ANSI B16.34 Class 150, 300, 400, 600, 900, 1500, or 2500</td>
<td>ANSI B1.20.1 and ANSI B16.11</td>
</tr>
<tr>
<td>Union end,(^a) silver-brazed</td>
<td>MIL-F-1183 (O-ring type) 400 lb/in.(^2) (2.758 MPa)</td>
<td>MIL-F-1183 (O-ring type) 400 lb/in.(^2) (2.758 MPa)</td>
</tr>
<tr>
<td>Union end,(^a) silver-brazed</td>
<td>803-1385946 1500</td>
<td>803-1385946 1500</td>
</tr>
<tr>
<td>Union end,(^a) silver-brazed</td>
<td>803-1385943 3000</td>
<td>803-1385943 3000</td>
</tr>
<tr>
<td>Union end,(^a) silver-brazed</td>
<td>803-1385884 6000</td>
<td>803-1385884 6000</td>
</tr>
<tr>
<td>Other, as specified (^a)</td>
<td>as specified</td>
<td>as specified</td>
</tr>
</tbody>
</table>

\(^a\)For union inlet and outlet end connections, only the pertinent dimensions listed in the applicable documents (Military Specification or NAVSEA requirements) shall apply. The valve shall be supplied with the thread pieces only, without the tail pieces and union nuts.
meeting all requirements of this specification and provide extended reliable operation when protected by a 5-µm nominal/18-µm absolute filter installed upstream and when subjected to conditions specified in Section 5.

6.1.2 *Materials of Construction*—Material requirements for the pressure-reducing valve shall be as follows: The pressure containing envelope (body, gas dome, or spring housing) shall be 300 series corrosion-resistant steel (304, 304L, 316, or 316L). Internal parts including springs, poppets, seal rings, and retainers shall be 300 series corrosion-resistant steel, nickel-aluminum bronze, nickel-copper (70–30), or bronze. Other materials for both the pressure-containing envelope and internal parts may be selected to assure compatibility with the line medium, weldability, and to provide corrosion resistance without requiring painting, coating, or plating. Materials for contacting parts shall be selected to minimize electrolytic corrosion and galling.

6.1.3 *Pressure Envelope*—The pressure-reducing valve shall be designed to pass a hydrostatic shell test at pressure(s) of at least 1.5 times the 100°F (38°C) pressure rating(s) of the valve without damage.

6.1.4 *Port Configuration*—The pressure-reducing valve shall have in-line inlet and outlet ports.

6.1.5 *Pressure Lines*—All pressure lines in the pressure-reducing valve shall be internally ported.

6.1.6 *Soft-Seating Insert*—A field replaceable soft-seating insert shall be incorporated in the pressure-reducing valve. Soft-seating inserts shall be protected from direct flow impingement, excessive loading and extrusion, or any other effect jeopardizing their useful life. Soft-seating inserts shall be of the simplest practical configuration to facilitate emergency replacement manufacture where necessary.

6.1.7 *Joints*—The bonnet or spring housing and bottom cap shall be attached to the body by bolting, a threaded connection, or a threaded union connection.

6.1.8 *Springs*—Any spring incorporated in the pressure-reducing valve shall not be compressed solid during operation. Spring ends shall be squared and ground. Engagement or disengagement of parts against spring compression shall not be permitted.

6.1.9 *Set Point Adjustment*—For mechanical spring-loaded pressure-reducing valves, the set point shall be adjustable under pressure and shall incorporate right-hand threads so that a clockwise rotation increases the set pressure. Means shall be used to prevent an accidental or inadvertent change in set pressure. The option of a tamper-proof set point adjustment shall be such that standard wrenches can be used on all external bolting. Lock-wire shall not be used. Any exposed threads shall be protected by plastic caps for shipping.

6.1.10 *Gas Dome*—For gas-dome loaded pressure-reducing valves, the set point shall be adjustable under pressure and shall maintain its charge without adjustment or recharge more frequently than once a year to remain within its specified performance envelope. Upstream pressure shall be used to establish dome load. Dome loading shall be accomplished by two valves installed in series, with a bleed-off valve in-between. If these valves are metal seated, they shall not seat directly into the structure of the dome so that damage or wear to the seating surfaces would not require repair or replacement of the dome. Only a single dome penetration is allowed. The valves shall be operable by a standard-size hex wrench or other suitable means. There shall be no external leakage past the threads during dome bleeding. Flow from the bleed-off valve shall be ported in such a way that it does not impinge directly on the person making the adjustment, cause excessive noise, or potentially lead to ice formation within the dome loading circuit.

6.1.11 *Threads*—Threads shall be as specified in ANSI B1.1. Where necessary, provisions shall be incorporated to prevent the accidental loosening of threaded parts. The design shall be such that standard wrenches can be used on all external bolting. Lock-wire shall not be used. Any exposed threads shall be protected by plastic caps for shipping.

6.1.12 *Accessability*—All internal parts of the pressure-reducing valve shall be accessible for adjustment or service, without removing the pressure-reducing valve from the line.

6.1.13 *Interchangeability*—The pressure-reducing valve including all associated piece parts, shall have part number identity, and shall be replaceable from stock or the manufacturer on a nonselective and random basis. Parts having the same manufacturer’s part number shall be directly interchangeable with each other with respect to installation (physical) and performance (function). Physically interchangeable assemblies, components, and parts are those that are capable of being readily installed, removed, or replaced without alternation, misalignment or damage to parts being installed or to adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.1.14 *Nonmetallic Element Interchangeability*—Nonmetallic elements, including but not limited to, soft-seating inserts, cushions, and O-rings, shall be treated as separately identified and readily replaceable parts.

6.1.15 *Maintainability*—Maintenance shall require standard tools to the maximum extent possible. Any special tools required for maintenance shall be identified, and shall be supplied as part of the valve.

6.1.16 *Reversibility*—Seating inserts shall not be physically reversible unless they are also functionally reversible to preclude incorrect assembly.

6.1.17 *Adjustments*—There shall be no adjustments required in the pressure-reducing valve during or after assembly other than the set point.

6.1.18 *Pressure Reversal*—The pressure-reducing valve shall not be damaged when subjected to a maximum pressure reversal (maximum set pressure exists at the outlet).

6.1.19 *Guiding*—The valve poppet shall be guided to prevent binding or seizing and ensure proper seating under all operating conditions. Proper alignment of all internal operating parts shall be maintained with interchangeable parts and under all tolerance stack-up conditions.

7. **Performance Requirements**

7.1 Pressure-reducing valves shall meet the performance requirements of 7.1.1–7.1.5.

7.1.1 *Flow Rate Demand Range*—The maximum and minimum flow rate demand required shall be specified (see Section
5) in standard cubic feet per minute [at 60°F (16°C) and 14.7 psia (101 kPa)]. The pressure-reducing valve shall meet the specified maximum and minimum flow rate demand requirements, or any intermediate flow rate demand requirement, and shall operate without hunting or chattering under all specified conditions.

7.1.2 Accuracy of Regulation—The pressure-reducing valve shall maintain set pressure within the accuracy of regulation limits specified in Table 2 under all flow rate demand and inlet operating pressure conditions specified.

7.1.3 Set Pressure Range—The set pressure range shall be as follows: Where the pressure-reducing valve is mechanically spring loaded, the set pressure shall be adjustable through a range of at least ±5% of the set pressure, or ±2 psi (13.8 kPa), whichever is greater. Where the pressure-reducing valve is gas dome loaded, the set point shall be adjustable through a range of at least ±25% of the set pressure or 10 psi (68.9 kPa), whichever is greater.

7.1.4 Seat Tightness—The pressure-reducing valve shall meet the seat tightness requirements of 8.1.3. Where necessary, leakage measurement shall start after temperature stabilization.

7.1.5 External Leakage—Pressure-reducing valve external leakage shall be bubble tight at operating pressure conditions over a 3-min period.

8. Tests Required

8.1 Each pressure-reducing valve must pass the tests outlined in 8.1.1-8.1.4.

8.1.1 Visual Examination—The pressure-reducing valve shall be examined visually to determine conformance with the ordering data, interface dimensions, and workmanship without disassembly.

8.1.2 Hydrostatic Shell Test—The pressure-reducing valve shall be hydrostatically tested with water by applying test pressure(s) not less than 1.5 times the 100°F (38°C) pressure rating(s) to the inlet and outlet ports to check structural integrity. Test pressure(s) shall be applied for 3 min. Air or nitrogen may be used in lieu of water, providing appropriate safety precautions are taken to minimize the risk associated with the use of a compressible fluid. There shall be no external leakage, permanent distortion, or structural failure.

8.1.3 Seal Tightness Test—The pressure-reducing valve shall be tested for seat tightness with air or nitrogen gas at an inlet test pressure not less than the maximum inlet operating pressure. The valve shall be isolated downstream using a dead-ended volume not exceeding ten diameters of downstream pipe and monitored with bubble fluid to assure tightness. There shall be no detectable rise in the outlet pressure over a 3-min period after pressure-reducing valve temperature stabilizes.

8.1.4 External Leakage Test—Air or nitrogen gas shall be applied to the inlet of the pressure-reducing valve at the rated pressure. External leakage shall be checked using bubble fluid or by submerging the pressure-reducing valve in water. There shall be no visible external leakage over a 3-min period.

9. Marking

9.1 Identification Plate—An identification plate of corrosion-resistant metal in accordance with Specification F 992, Types I, II, III, or IV shall be permanently attached to the pressure-reducing valve and shall include the following information (some or all information may instead be stamped or etched directly on the outside surface of the pressure-reducing valve):

9.1.1 Manufacturer’s name,
9.1.2 ASTM designation and year of issue,
9.1.3 Valve size, type, and pressure rating(s),
9.1.4 Nominal operating conditions (inlet pressure, set pressure, and flow capacity),
9.1.5 Manufacturer’s model/part number.

10. Quality Assurance System

10.1 The manufacturer shall establish and maintain a quality assurance system that will ensure all the requirements of this specification are satisfied. This system shall also ensure that all valves will perform in a similar manner to those representative pressure-reducing valves subjected to original testing for determination of the operating and flow characteristics.

10.2 A written description of the quality assurance system the manufacturer will use shall be available for review and acceptance by the inspection authority.

10.3 The purchaser reserves the right to witness the production tests and inspect the pressure-reducing valves in the manufacturer’s plant to the extent specified on the purchase order.

<table>
<thead>
<tr>
<th>TABLE 2 Required Accuracy of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set Pressure, psig</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>0–9 (0–69 kPa)</td>
</tr>
<tr>
<td>10–25 (70–172 kPa)</td>
</tr>
<tr>
<td>26–50 (173–345 kPa)</td>
</tr>
<tr>
<td>51–100 (346–689 kPa)</td>
</tr>
<tr>
<td>101–250 (690–1725 kPa)</td>
</tr>
<tr>
<td>251–750 (1726–5170 kPa)</td>
</tr>
<tr>
<td>751–1000 (5171–6895 kPa)</td>
</tr>
<tr>
<td>Above 1000 (above 6896 kPa)</td>
</tr>
</tbody>
</table>
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements S1, S2, or S4 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Supplemental Tests

S1.1 Qualification tests shall be conducted at a facility satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.1.1 through S1.1.7 and delineated in the ordering data. The tests may be conducted on representative valve sizes and pressure classes to qualify all sizes and pressure classes of valves, provided the valves are of the same type and design. Evidence of prior approval of these tests is acceptable.

S1.1.1 Pressure Reversal Test—The pressure-reducing valve shall be tested to determine the susceptibility to damage when subjected to pressure reversal as specified in 6.1.18. It shall be set up with maximum inlet operating pressure and maximum set pressure. A separate means shall be included to insure that there is no loss of downstream pressure during this test. The reference load shall then be removed from the set-point mechanism (if the pressure-reducing valve is spring loaded, all spring compression shall be backed off, if it is gas dome loaded, all dome charge shall be released). The inlet pressure shall then be released and this condition (no load on the pressure-reducing valve set point mechanism, zero pressure applied to the inlet side of the pressure-reducing valve seat, and maximum set pressure applied to the outlet side of the pressure-reducing valve seat) shall be maintained for a period of not less than 1 h. There shall be no leakage from the outlet to the inlet of the pressure-reducing valve seat) shall be maintained for a period of not less than 1 h. There shall be no leakage from the outlet to the inlet of the pressure-reducing valve seat. There shall be no evidence of damage to the pressure-reducing valve and no degradation to its performance capability.

S1.1.2 Accuracy of Regulation Test—The pressure-reducing valve shall be tested for accuracy of regulation at each inlet pressure/set pressure combination shown in Table S1.1. At Condition D, flow shall be varied over the full range of flow rate demand as specified in Section 5. For Conditions A, B, and C, full flow range testing is not required. During each sequence (changing from Condition A to Condition B and changing from Condition C to Condition D), no alteration shall be made to the set pressure adjustment, or any other portion of the pressure-reducing valve, and the accuracy of regulation shall be maintained as required by Table 2. There shall be no instability or other evidence of unsatisfactory operation of pressure-reducing valve during these tests. Flow in each condition shall be maintained long enough to demonstrate that the above requirements are met.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Inlet Pressure</th>
<th>Set Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>maximum</td>
<td>minimum</td>
</tr>
<tr>
<td>B</td>
<td>minimum</td>
<td>minimum</td>
</tr>
<tr>
<td>C</td>
<td>maximum</td>
<td>maximum</td>
</tr>
<tr>
<td>D</td>
<td>minimum</td>
<td>maximum</td>
</tr>
</tbody>
</table>

S1.1.3 Shock Test—The pressure-reducing valve shall be subjected to and meet the high-impact shock tests for Grade A, Class I as specified in MIL-S-901 pressurized with air or nitrogen gas. The inlet port shall be pressurized to the maximum inlet operating pressure and the outlet port pressurized to the maximum outlet operating pressure. There shall be no structural damage to the pressure-reducing valve or any components. There shall be no degradation to the performance capability of the pressure-reducing valve. Momentary loss in pressure is permissible.

S1.1.4 Vibration Test—The pressure-reducing valve shall be vibration tested in accordance with Type 1 of MIL-STD-167-1 pressurized with air or nitrogen gas. The inlet port shall be pressurized to the maximum inlet operating pressure and the outlet port pressurized to the maximum outlet operating pressure. At frequencies up to and including 33 Hz (unless otherwise specified in Section 5), there shall be no resonance in the range of frequency tested. There shall be no structural damage or degradation to the performance capability of the pressure-reducing valve.

S1.1.5 Noise Test—The pressure-reducing valve shall be tested for airborne noise in accordance with MIL-STD-740-1. The noise (sound pressure level) shall not exceed 85 db observed at 1-m distance from the pressure-reducing valve.

S1.1.6 Posttest Examination—The pressure-reducing valve shall be disassembled and examined for any evidence of excessive wear, degradation, or impending damage or breakage.

S1.1.7 Spring Deflection Test—The springs used in the pressure-reducing valves shall not exhibit a permanent set when compressed 20 % beyond their design limits. A spring deflection test shall be conducted to verify compliance to this requirement.

S2. Technical Data and Certification Requirements

S2.1 Drawings—Assembly drawings or catalog sheets of the pressure-reducing valve that clearly depict design and shall be provided. The following information shall also be included as part of the drawings or catalog sheets:

S2.1.1 Bill of material listing specification, grade, condition, and any other data required to identify fully the properties of the materials proposed. This shall include identifications, material and size designations, shore hardness and any other data necessary to identify fully the parts.

S2.1.2 In cases in which standard commercial or military parts are or can be used, these shall be appropriately identified.

S2.1.3 Outline dimensions, disassembly space, location, and size of end connections.

S2.1.4 Estimated weight and center of gravity (vertical, longitudinal, and transverse).
S2.1.5 Recommended assembly torques or equivalent procedures for making up all joints and threaded assemblies.
S2.1.6 The following valve performance information shall be included:
S2.1.6.1 Set pressure and adjustable range.
S2.1.6.2 Specified operating conditions—range of inlet pressures and required range of capacity.
S2.1.6.3 Fail-open capacity (for purposes of pressure-relief valve sizing) of the pressure-reducing valve.
S2.2 Technical Manuals—Technical manuals shall provide a description, installation procedures, operation and maintenance instructions, and illustrated parts breakdown for the pressure-reducing valve, organized as follows:
S2.2.1 Chapter 1—General Information and Safety Precautions.
S2.2.2 Chapter 2—Operation.
S2.2.3 Chapter 3—Functional Description.
S2.2.4 Chapter 4—Scheduled Maintenance.
S2.2.5 Chapter 5—Troubleshooting.
S2.2.6 Chapter 6—Corrective Maintenance.
S2.2.7 Chapter 7—Parts List.
S2.2.8 Chapter 8—Installation.
S2.2.9 In addition, the following shall be included as part of the technical manual content:
(a) The assembly drawings for the pressure-reducing valve, supplemented by additional illustrations where necessary to illustrate operation and maintenance adequately. These additional illustrations may consist of blowouts, partial or full sections, and may eliminate extraneous lines and details to clarify the interaction of parts.
(b) Table listing wrench sizes and assembly torques or other equivalent procedures for making up all joints and threaded assemblies.
(c) Detailed disassembly and reassembly and procedures. In addition to a section providing procedures for the complete disassembly and reassembly of the pressure-reducing valve, maintenance and troubleshooting sections shall contain, or refer to, only the limited disassembly and reassembly required to accomplish each particular operation. This is intended to reduce the possibility of unnecessary disassembly and unnecessary disturbance of adjustments when performing specific or limited maintenance or troubleshooting operations.
S2.3 Certification—Certification shall be provided indicating that the valve meets all requirements of the purchase order.

S3. Quality Assurance
S3.1 Scope of Work—The written description of the quality assurance system shall include the scope and locations of the work to which the system is applicable.
S3.2 Authority and Responsibility—The authority and responsibility of those in charge of the quality assurance system shall be clearly established.
S3.3 Organization—An organizational chart showing the relationship between management and the engineering, purchasing, manufacturing, construction, inspection and quality control groups is required. The purpose of this chart is to identify and associate the various organizational groups with the particular functions for which they are responsible. These requirements are not intended to encroach on the manufacturer’s right to establish, and from time to time to alter, whatever form of organization the manufacturer considers appropriate for its work. Persons performing quality control functions shall have a sufficiently well-defined responsibility and the authority and the organization freedom to identify quality control problems and to initiate, recommend, and provide solutions.
S3.4 Review of Quality Assurance System—The manufacturer shall ensure and demonstrate the continuous effectiveness of the quality assurance system.
S3.5 Drawings, Design Calculations, and Specification Control—The manufacturer’s quality assurance system shall include provisions to ensure that the latest applicable drawings, design calculations, specifications and instructions, including all authorized changes, are used for manufacture, examination, inspection, and testing.
S3.6 Purchase Control—The manufacturer shall ensure that all purchased material and services conform to specified requirements and that all purchase orders give full details of the material and services ordered.
S3.7 Material Control—The manufacturer shall include a system for material control that ensures the material received is properly identified and that any required documentation is present, identified to the material, and verifies compliance to the specified requirements. The material control system shall ensure that only the intended material is used in manufacture. The manufacturer shall maintain control of material during the manufacturing process by a system which identifies status of material throughout all stages of manufacture.
S3.8 Manufacturing Control—The manufacturer shall ensure that manufacturing operations are carried out under controlled conditions using documented work instructions. The manufacturer shall provide for inspection, where appropriate, for each operation that affects quality or shall arrange an appropriate monitoring operation.
S3.9 Quality Control Plan—The manufacturer’s quality control plan shall describe the fabrication operations, including examination and inspections.
S3.10 Welding—The quality control system shall include provisions for ensuring that welding conforms to specified requirements. Welders shall be qualified to the appropriate standards and the qualification records shall be made available to the inspection authority if required.
S3.11 Nondestructive Examination—Provisions shall be made to use nondestructive examination, as necessary, to ensure that material and components comply with the specified requirements. Nondestructive examinations shall be authorized by their employer and/or qualified by a recognized national body, and their authorizations/qualification records shall be made available to the inspection authority if required.
S3.12 Nonconforming Items—The manufacturer shall establish procedures for controlling items not in conformance with the specified requirements.
S3.13 Heat Treatment—The manufacturer shall provide controls to ensure that all required heat treatment have been applied. Means should be provided by which heat treatment requirements can be verified.
S3.14 Inspection Status—The manufacturer shall maintain a system for identifying the inspection status of material during
all stages of manufacture and shall be able to distinguish between inspected and non-inspected material.

S3.15 *Calibration of Measurement and Test Equipment*—The manufacturer shall provide, control, calibrate, and maintain inspection, measuring, and test equipment to be used in verifying conformance to the specified requirements. Such calibration shall be traceable to a national standard and calibration records shall be maintained.

S3.16 *Records Maintenance*—The manufacturer shall have a system for the maintenance of inspection records, radiographs, and manufacturer’s data reports that describe the achievement of the required quality and the effective operation of the quality system.

S3.17 *Sample Forms*—The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description of the quality assurance system shall make reference to these forms.

S3.18 *Inspection Authority*—The manufacturer shall make available to the inspection authority at the manufacturer’s plant a current copy of the written description of the quality assurance system. The manufacturer’s quality assurance system shall provide for the inspection authority at the manufacturer’s plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the inspection authority to perform its duties in accordance with this supplementary requirement. The manufacturer may provide for such access by furnishing the inspection authority with originals or copies of such documents.

S4. **Special Material, Design, and Performance Requirements**

S4.1 *Recovered Materials*—Unless otherwise specified herein, all equipment, material, and articles incorporated in the products covered by this specification shall be new and may be fabricated using materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term “recovered materials” means materials that have been collected or recovered from solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or rebuilt products is allowed under this specification unless otherwise specified.

S4.2 Pipe threads shall not be used in the pressure-reducing valve.

S4.3 *Envelope Dimensions*—Pressure-reducing valve envelope dimensions (see X1.5) shall be as specified in Fig. 1 and Table S4.1.

S4.4 *Nonmetallic Valve Internal Parts*—Nonmetallic internal parts shall be compatible with any residual materials (100% humidity, entrained salt spray, and 2190 TEP lubricating oil used in air compressors) in the line media.

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**FIG. 1 Pressure−Reducing Valve Envelope Dimensions**
APPENDIX

(Nonmandatory Information)

X1. GUIDELINES FOR SELECTION OF PRESSURE-REDUCING VALVES

X1.1 Scope—This appendix provides general guidelines for the selection of pressure-reducing valves, and therefore, its use does not in any way relieve the user of the final responsibility in the selection and installation of pressure-reducing valves.

X1.2 Mode of Operation—Pressure-reducing valves for air or nitrogen service are commonly designed to operate in one of three basic modes:

X1.2.1 Direct Spring Loaded—Set point established by a mechanical spring; generally practical at only small-to-moderate combinations of flow demand and set pressure.

X1.2.2 Gas Dome Loaded—Set point established by a fixed gas charge loaded into the dome from the valve inlet at the time the valve is set; generally advantageous for high combinations of flow demand and set pressure.

X1.2.3 Gas Dome Loaded, Pilot Referenced—Set point established by a charge of gas in the dome which is maintained constant at all times by a spring-loaded pilot valve installed on or adjacent to the dome and which operates by sensing the pressure in the dome and either venting the dome, or charging the dome, using gas drawn from the valve inlet, as necessary. This arrangement, also known as a compensator, compensates for temperature change, valve stroke, leakage, or any other condition which would otherwise cause a change in dome pressure and thus set point.

X1.3 Fail-Open Capacity—It is critical to establish accurately and define clearly the fail-open capacity of a pressure-reducing valve. This parameter establishes the requirements for the pressure-relief valve that protects the system downstream of the pressure-reducing valve from overpressure in the event of pressure-reducing valve failure.

X1.4 Valve Types—Pressure-reducing valves covered by this specification are defined by type as follows:

X1.4.1 Type 1—Valves that have inlet and outlet connections that are identical.

X1.4.2 Type 2—Valves that have inlet and outlet connections that are not identical. These valves can facilitate any configuration, increase in size, or decrease in rating downstream of the regulator as a result of the pressure reduction in the flow path accomplished by the pressure-reducing valve.

X1.5 Pressure-reducing valves intended for use in manifolds per the applicable ASTM specification on manifolds (Specification F 1685), should be Type I, with union end connections in accordance with Table 1 and envelope dimensions in accordance with Fig. 1 and Table S4.1.

<table>
<thead>
<tr>
<th>Valve Size</th>
<th>A (in.)</th>
<th>A (mm)</th>
<th>B (in.) (Max)</th>
<th>B (mm) (Max)</th>
<th>C (in.)</th>
<th>C (mm) (Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 NPS (13.5 mm)</td>
<td>6 1/4 ± 3/64</td>
<td>158 ± 5</td>
<td>3 1/2</td>
<td>89</td>
<td>3</td>
<td>76</td>
</tr>
<tr>
<td>3/8 NPS (17.2 mm)</td>
<td>7 ± 3/32</td>
<td>178 ± 5</td>
<td>4 1/4</td>
<td>108</td>
<td>4</td>
<td>102</td>
</tr>
<tr>
<td>1/2 NPS (21.3 mm)</td>
<td>8 ± 1/16</td>
<td>203 ± 6</td>
<td>5</td>
<td>127</td>
<td>4 1/2</td>
<td>114</td>
</tr>
<tr>
<td>5/8 NPS (26.9 mm)</td>
<td>9 ± 1/8</td>
<td>229 ± 6</td>
<td>5 3/4</td>
<td>146</td>
<td>5</td>
<td>127</td>
</tr>
<tr>
<td>3/4 NPS (33.7 mm)</td>
<td>10 ± 1/4</td>
<td>254 ± 6</td>
<td>6 1/4</td>
<td>165</td>
<td>5 3/4</td>
<td>146</td>
</tr>
</tbody>
</table>

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Standard Guide for  
Shipboard Generated Waste Management Audits

This standard is issued under the fixed designation F 1799; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Purpose—This guide covers information for assisting shipowners in planning for costs or scheduling complications during maintenance, repair, modifications, purchase negotiations, or scrapping activities. Removal and disposal of certain materials disturbed during modification, maintenance, or disposal of systems or components may be costly or interrupt the work schedule.

1.2 Objectives:

1.2.1 This guide will describe materials that may be disturbed on ships during maintenance or scrapping activities, which may result in costly or time-consuming removal or disposal actions.

1.2.2 This guide will provide a systematic method to identify and record the locations of materials of concern for immediate planning and future reference.

1.2.3 This guide will include a brief discussion of issues related to the handling and storage of materials described in this guide.

1.3 Considerations Beyond Scope:

1.3.1 This guide is not intended to address materials carried as cargo or material stored onboard in prepackaged containers.

1.3.2 This guide is not intended to address waste products related to the ongoing, day-to-day operation of a ship, such as sewage, solid waste, incinerator ash (or other residual products resulting from solid waste treatment), and residual sludge left in segregated ballast tanks.

1.3.3 This guide does not provide a comprehensive index of test methods available for characterizing the materials discussed. Test methods referenced or described should be considered as examples.

1.3.4 This guide is not intended to address directly regulatory issues for any of the materials described.

1.3.5 This guide is not intended to address remediation concerns.

2. Referenced Documents

2.1 ASTM Standards: 2

D 923 Practices for Sampling Electrical Insulating Liquids
E 849 Practice for Safety and Health Requirements Relating to Occupational Exposure to Asbestos

2.2 ASHRAE Standards: 4

ASHRAE Guideline 3, Reducing Emission of Fully Halogenated Chlorofluorocarbon (CFC) Refrigerants in Refrigeration and Air-Conditioning Equipment and Applications

2.3 EPA Methods: 5

EPA 600/M4–82–020, Interim Method of the Determination of Asbestos in Bulk Insulation Samples
EPA SW-846, Method 8080, Organochlorine Pesticides and PCBs
EPA SW-846, Method 1311, Toxicity Characteristic Leachate Procedure
EPA SW-846, Method 8270, Semi-Volatiles List
EPA SW-846, Method 8260, Volatiles List

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 audit, n—a process to identify waste materials associated with maintenance, repair, modifications, purchase negotiations, or scrapping activities, some of which may be hazardous, with the goal of providing planning information about environmental, health, and safety risks and related costs.

3.1.2 friable, adj—a physical state in which a dry material can be easily crumpled, pulverized, or reduced to powder by hand pressure.

3.1.3 mobile, adj—capable of being transported from one surface to another.

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2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

3 Withdrawn.

4 Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.

3.1.4 PCB, \( n \)—a class of chemicals comprised of polychlorinated biphenyls.

3.1.5 streaming agents, \( n \)—a type of chemical used to fight small, contained fires by directing the firefighting agent specifically at the fire.

3.1.6 target materials, \( n \)—specific materials that the audit process will identify for evaluation.

3.1.7 waste oil, \( n \)—oil that cannot be reused or recycled.

4. Significance and Use

4.1 Applicability—This guide is intended to describe a planning audit that will improve the shipowner’s ability to forecast costs and schedule impacts and aid the shipowner in identifying environmental, health, and safety concerns associated with the removal, handling, and disposal of potentially hazardous shipboard materials.

4.2 Use—Audits may be performed to aid in planning for a variety of events, including maintenance, repair, modification, purchase, or scrapping. To maximize efficiency, audits should be tailored to meet the specific needs of the shipowner, with target materials identified during the planning process.

4.3 Caution—Legal restrictions on the removal and disposal of materials discussed in this guide may vary significantly from port to port, both within the United States and abroad. Reasons for this variation include the decentralized nature of port control, state, and local environmental regulations, and the local availability of landfill or treatment facilities. Users of this guide should consult local authorities to obtain information on specific legal requirements.

5. Procedure

5.1 Planning—Objectives for the waste management audit should be established at the planning stage. A well-planned audit will focus on target materials in critical locations to minimize audit costs. Waste management audits, therefore, should be performed by environmental, health, and safety experts familiar with the specific objectives of the audit. Past audit reports of the area and other documentation that may provide insight into material characterization should be reviewed to avoid the expense of unnecessary tests. For example, construction specifications may characterize a particular material, eliminating the need for testing. In some instances, inspection of the ship or interviews with personnel on-site may be beneficial in planning the audit.

5.2 Testing—Many materials will require sampling and characterization tests. A sampling plan should be followed by qualified and authorized personnel. Analysis performed by a qualified or certified laboratory may be required.

6. Potential Shipboard Generated Wastes

6.1 Asbestos:

6.1.1 Description—Asbestos is the common name of a number of substances including amosite, anthrophyllite, amphibole, and chrysotile (1). When asbestos becomes friable, it may be inhaled or swallowed, penetrating body tissues and remaining there for many years. Exposure to asbestos has been linked to asbestososis, mesothelioma, and other cancers. Exposure to cigarette smoke may increase the long-term risk of developing asbestos-related lung cancer by as much as 90%.

6.1.2 Uses—Many common construction products contain asbestos, although use of the material in the United States was significantly reduced during the 1970s. Likely products include pipe lagging and other types of insulation, vinyl tile and linoleum, floor tile adhesives, cement sheet and fiberboard, brake pads and linings, and gasket materials, particularly for high-temperature applications.

6.1.3 Test Methods (for Thermal Insulation) (2):

6.1.3.1 Sampling—The area to be sampled should be subdivided into homogeneous areas, and sampling of each homogeneous area should be conducted in a statistically random manner. For surface materials, collect at least three samples for each area under 1000 ft\(^2\), at least five for areas between 1000 and 5000 ft\(^2\), and at least seven for each area greater than 5000 ft\(^2\). For piping insulation, collect at least three samples from each homogeneous section of piping.

6.1.3.2 Analysis—Samples should not be composited for analysis. Analysis of each sample should be conducted using the Polarized Light Microscopy Method described in EPA 600/M4-82-020. Under current U.S. regulations, a homogeneous area may be considered free of asbestos if all samples from that area are shown to contain less than 1 % of asbestos.

6.1.4 Handling Precautions (3)—Asbestos should only be handled by trained personnel. If asbestos must be disturbed, the area should be isolated and well-labeled to protect employees not involved with the removal or repair work. Protective clothing including disposable coveralls, gloves, goggles, and a respirator should be worn when handling asbestos, and personnel should remove contaminated clothes and wash before leaving the work site. Material should be kept wet to minimize potential for airborne fibers. Waste products should be stored in plastic bags in a sealed rigid container and protected from physical damage. Asbestos material, including asbestos waste, should be stored in an isolated, regulated, and well-marked area. Smoking, eating, drinking, chewing, or applying cosmetics should be avoided in areas in which asbestos exposure is likely. Practice E 849 provides additional details. Asbestos replacement materials also may pose environmental, safety, and health risks.

6.2 PCB-Contaminated Media:

6.2.1 Description—PCBs have many useful properties including high stability, low vapor pressure, low flammability, high heat capacity, and low electrical conductivity. They are suspected carcinogens, however, and have been associated with adverse health and reproductive effects. They also have a high potential for bioaccumulation in the food chain. A number of trade names exist for PCBs, including Aroclor, Asbestol, Chlorextol, Diaclor, and Dykanol (4).

6.2.2 Uses—Because of the many positive characteristics of PCBs, oils containing PCBs have been used in a great variety of applications. The most common use has been as a dielectric fluid in transformers, capacitors, and other electrical equipment. The oil also has been used in many other situations
including hydraulic equipment, paints, oil-soaked gasket material, and as a plasticizer in many other products. PCBs have been banned in the United States since the mid-1970s, but materials manufactured after the ban have been found to contain them. Applications involving mobile forms of PCBs pose a much greater risk to personnel and the environment. Typical shipboard materials that may contain mobile forms of PCBs include electrical equipment containing dielectric fluid, oil-soaked gasket material, oil-soaked insulation material, and hydraulic fluids.

6.2.3 Test Methods:

6.2.3.1 Sampling—Because of significant variation in the PCB content of similar materials, mixing or combining samples prior to analysis is not recommended. Similarly, random samples cannot prove untested items either to contain or to be free of PCBs. Liquid oils may be sampled using Practices D 923.

6.2.3.2 Analysis—Materials may be analyzed using EPA SW-846, Method 8080.

6.2.4 Handling Precautions—PCBs should only be handled by trained personnel. Protective equipment should be worn when handling PCBs, with particular attention to avoiding skin and respiratory exposure. Work spaces should be well ventilated.

6.3 Refrigerants:

6.3.1 Description—Refrigerants present similar health and environmental dangers and may be discussed as a group. Many refrigerants are ozone-depleting substances. In general, refrigerants are relatively safe and stable gases, but may displace oxygen to dangerously low levels when released into confined spaces. Some refrigerants also may have acute toxic effects or result in increased cardiac sensitization at high concentrations.

6.3.2 Uses—A number of chemicals are used as refrigerants in shipboard air conditioning or refrigeration systems. Almost all are halocarbons, with CFC 12 and HCFC 22 being the most common of the traditional refrigerants. Concern for the ozone-depleting potential of these substances has led to the introduction of another common refrigerant, HFC 134a.

6.3.3 Test Methods—Identification of materials typically will not require testing. A quick review of system technical manuals should reveal the refrigerant used in the system, and any bottles containing refrigerant gas should be labeled.

6.3.4 Handling Precautions—Work on air conditioning and refrigeration systems should be performed only by qualified personnel. Refrigerants should not be intentionally released to the atmosphere. Refrigerants present in air conditioning or refrigeration equipment should be recovered and recycled (refrigerants typically have a high resale or recycling value), as described in ASHRAE Guideline 3. If accidental release occurs, personnel should leave the area and avoid inhaling vapors. Personnel requiring emergency medical attention following inhalation of refrigerants should not be given catecholamine drugs, such as epinephrine, because of the potential for increased cardiac sensitization. As a result of possible toxic by-products of combustion, refrigerants should be kept away from open flame. Smoking should not be allowed in areas in which refrigerants may leak to the atmosphere.

6.4 Used or Waste Oils:

6.4.1 Description—Waste oils include a variety of oil products that have been contaminated through use or storage to the point at which they can no longer be used for their intended purpose. Many used oils can be recycled. This category does not include water contaminated with small amounts of oil, which is addressed in 6.7.

6.4.2 Uses—The primary sources of shipboard used or waste oils are from hydraulic systems, engine room machinery, lubricating systems, and fuel systems.

6.4.3 Test Methods—Tests for halogen content and flash point are the most common, but test procedures will vary depending on the intended disposal method and suspected contaminants.

6.4.4 Handling Precautions—Recycling may include processes, such as reclamation, burning for energy recovery, reprocessing, or re-refining. The recycling potential of a used oil product will be dependent on the quantity of contaminants present. Contaminants may include arsenic, cadmium, chromium, lead, PCBs, sulfur, hydrogen sulfide, or halogens (chlorine, fluorine, and bromine). Unusually low flash points also may limit recycling potential, as will the presence of dispersants or emulsifying agents. Table 1 summarizes potential recycling problems associated with a variety of common oil products.

6.5 Paint Products:

6.5.1 Description—Paint often contains toxic constituents. Intact paint typically poses little risk, but exposure to toxic materials may occur during spraying, sanding, grinding, burning, or abrasive blasting procedures with paints containing even trace amounts of toxic chemicals. Potential toxic constituents in paint include fluoride salts and compounds of heavy metals. Toxic organic compounds such as benzene and toluene may be present in paint solvents. Toxic constituents are a concern because of the need to protect those applying or disturbing paint and because of disposal concerns associated with paint chips and contaminated blast grit. Paint found on older ships is of particular concern, as many layers of paint may be found in a single location.

6.5.2 Uses—Not applicable.

6.5.3 Test Methods—Old paint, applied to surfaces, may require analysis to determine toxic content before disturbing it.

6.5.3.1 Sampling—Care should be taken to ensure that samples are representative of the material being sampled. A representative sample should include all layers of paint.

6.5.3.2 Analysis (5)—While laboratory methods can determine the total quantity of toxic constituents in the paint, the capacity for the toxic constituents to leach out into the

| TABLE 1 Potential Recycling Problems Associated with a Variety of Common Oil Products |
|---------------------------------|---------------------------------|
| Product                         | Potential Problems              |
| Aviation fuels                  | low flash point, fire hazard     |
| Refrigeration lubricants        | halogenated hydrocarbon detergents/emulsifiers will not dissolve hazardous contaminants incompatible with petroleum products |
| Tank slops (from tank cleaning) |                                  |
| Grease (from trap cleaning), sludges |                          |
| Oily wastes: waste oil sludge, waste fuel oil, waste lubricant |                      |
| Synthetic oil                   |                                  |

surrounding environment may be determined using the Toxicity Characteristic Leachate Procedure, EPA SW-846, Method 1311.

6.5.4 Handling Precautions—Virtually all paint products contain some toxic constituents. Even small amounts of toxic materials present in paint coatings can result in some airborne exposure during spraying, sanding, grinding, burning, or abrasive blasting procedures, so protective equipment, including respirators and disposable clothing, should be used consistently to minimize risk to personnel, and work areas should be cleaned and well ventilated to remove any contaminated dust or debris (6). Dust, debris, and other waste materials with a high leachable toxic content may pose a long-term disposal problem as a result of potential contamination of landfills and groundwater near the disposal site.

6.6 Cleaning Products:

6.6.1 Description—Many cleaning products contain toxic chemicals. In some cases, large doses of these chemicals would be required for any adverse effect to human health, but some exposure paths require only small quantities of a chemical. Also, some cleaning products may interfere with the effectiveness of shipboard oily water separators. Also, sewage treatment plants using microbes to break down waste products can be damaged by the use of even small quantities of toxic materials.

6.6.2 Uses—Household cleaners, industrial solvents, and other cleaning products are found throughout most ships.

6.6.3 Test Methods—In most cases, cleaning products will be labeled clearly, making analysis unnecessary.

6.6.4 Handling Precautions—Specific handling and disposal instructions should be available through the manufacturer. Check for technical information, such as an MSDS.

6.7 Oily Water:

6.7.1 Description—Oily water is comprised primarily of oil and water, typically less than 5 % oil, but may contain other contaminants.

6.7.2 Uses—Sources for shipboard oily water include tank cleaning wastes, dirty ballast water, and water collecting in bilge spaces.

6.7.3 Test Methods—In some locations, tests are performed to determine the disposal requirements for oily water. If the oily water is suspected of containing solvents or other contaminants, the following tests are typically performed (others may be required): flash point, lead, zinc, tin, mercury, and carcinogenic materials.

6.7.4 Handling Precautions—The separation of a pure oil/water mixture is a relatively simple process, resulting in water of a high enough quality to be reintroduced into the environment in some locations and oil of a high enough quality to be burned for energy recovery. The presence of lead, mercury, or other toxic contaminants in the mixture may restrict disposal options, and the presence of emulsifying agents or detergents in the mixture may impair the separation process.

6.8 Soiled Rags:

6.8.1 Description—Rags used to clean any surface contaminated with oils, greases, solvents, or paints. Soiled rags are most often generated in machinery rooms, but also may be generated during maintenance on deck gear or in habitability areas.

6.8.2 Uses—Not applicable.

6.8.3 Test Methods—Not applicable.

6.8.4 Handling Precautions—Soiled rags should be bundled and carefully stored for disposal ashore. Rags soaked with oils, solvents, or paints may be highly flammable and have been known to combust spontaneously. Soiled rags should be stored in sealed containers in well-ventilated spaces and kept away from flame and high temperatures to minimize risk of fire.

6.9 Chemically Treated Water:

6.9.1 Description—Chemicals are often added to alter the water quality. These may include deoxidizing agents, such as hydrazine or sodium sulfate, added to minimize corrosion. Water also is treated with chemicals, such as lime, to reduce water hardness and prevent fouling. Ethylene glycol often is added to prevent water from freezing.

6.9.2 Uses—Most chemically treated water is found in boilers, condensers, and jacket water-cooling systems. Semi-permanent ballast water may also contain chemical additives.

6.9.3 Test Methods—Inspection of maintenance records should reveal chemical treatments used on the ship, eliminating the need for testing under most circumstances.

6.9.4 Handling Precautions—Options for discharge or disposal of chemically treated water may be restricted based on local discharge regulations or agreements. A high concentration of dissolved chemicals in the water may limit disposal options, as municipal water systems, which often eventually receive chemically treated water, typically prohibit certain contaminants. Table 2 and Table 3 provide additional information on common contaminants and their effect on water systems.

6.10 Firefighting Agents:

6.10.1 Description—Firefighting agents can be one of two general types. Streaming agents typically are handheld units used to direct the material at a fire source and usually are found in small canisters located throughout the ship. Flooding agents are typically installed systems designed to provide a large quantity of material throughout an area in which a fire is occurring and usually are found in large quantities in a central location with piping systems carrying the agent to distribution points.

6.10.2 Uses—Water, Halons, foaming agents, powders, and carbon dioxide are common firefighting agents.

<table>
<thead>
<tr>
<th>TABLE 2 Contaminants That May Limit Disposal Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Chlorine, surfactant, chloride, sulfate, antimony,</td>
</tr>
<tr>
<td>arsenic, beryllium, tin, formaldehyde, organic</td>
</tr>
<tr>
<td>solvents, strong oxidizing agents (including acids,</td>
</tr>
<tr>
<td>bleaches, and stripping and cleaning materials),</td>
</tr>
<tr>
<td>strong reducing agents (ammonia)</td>
</tr>
<tr>
<td>Thallium, cyanide, cadmium, chromium, copper, lead,</td>
</tr>
<tr>
<td>mercury, nickel, selenium, silver, zinc, radioactivity</td>
</tr>
<tr>
<td>Temperature, pH</td>
</tr>
<tr>
<td>Oil and grease</td>
</tr>
</tbody>
</table>
TABLE 3 Common Prohibited Inputs to Sewage Systems

| Gasoline, fuel oil, and other flammable or explosive materials |
| Toxics, noxious, or poisonous materials |
| Ashes, cinders, sand, mud, glass, paper, rags, string, metals, plastics, feathers, or other materials likely to obstruct flow |

6.10.3 Test Methods—In most cases, firefighting agents will be labeled clearly making analysis unnecessary.

6.10.4 Handling Precautions—Cylinders of compressed gas should be handled gently, particularly if age or contents are unknown. Halons are ozone-depleting substances and should not be released to the atmosphere except in firefighting situations. Many firefighting agents are toxic, and direct contact with skin or through inhalation should be avoided. Specific handling and disposal instructions should be available through the manufacturer or distributor of the agent.

6.11 Unknown Material:

6.11.1 Description—Unlabeled containers of potentially hazardous material may be found. Identification of such containers through chemical analysis is costly, but necessary to ensure safe handling and disposal.

6.11.2 Uses—Not applicable.

6.11.3 Test Methods—The Toxicity Characteristic Leachate Procedure, EPA SW-846, Methods 1311 with the Method 8270 (Semi-Volatiles List) and Method 8260 (Volatiles List) may be used to identify hazardous constituents. Laboratory analysis should provide tentatively identified compounds (TIC) for any hazardous constituents identified. In some instances, tests for various heavy metals also may be appropriate.

6.11.4 Handling Precautions—Unknown material should be handled with extreme care and only by trained personnel wearing appropriate personal protective equipment. Contents of unlabeled containers should never be mixed. Smoking, eating, or drinking in the vicinity of unknown, but potentially hazardous, material should be avoided. Disposal alternatives will vary depending on the result of chemical analysis.

7. Documentation

7.1 Audit Report:

7.1.1 Summary—A summary section briefly describing the audit objectives and any notable conclusions that have been drawn from the audit.

7.1.2 Auditing Personnel—A complete list of auditing personnel, their accreditation and their affiliation to the vessel being audited.

7.1.3 Objectives—A description of the specific objectives and goals for the audit.

7.1.4 Target Shipboard-Generated Wastes—A list of target materials that will be included in the audit.

7.1.5 Test Methods—A specific description or reference to test methods used to identify the presence of target materials.

7.1.6 Results—A summary of the test results arranged in a clear and concise format.

7.1.7 Conclusions—A summary of target materials identified, handling and disposal options available, and a description of unanswered questions or concerns arising from the audit.

7.1.8 Appendices—May contain laboratory reports or other information supplementing the report described previously.

7.2 Record Retention—Audit reports and other supporting information should be retained in a central file as technical documentation for the ship. Supporting documents may be retained with audit reports to streamline the planning process for future audits.

8. Keywords

8.1 audit; hazardous material; hazardous waste; shipboard-generated wastes; ships; waste

REFERENCES


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Standard Guide for
Weight Control Technical Requirements for Surface Ships

1 This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

1 Annual Book of ASTM Standards, Vol 01.07.
3.1.10 vertical center of gravity (KG or VCG), n—the point through which the gravitational forces on a ship pass measured vertically from the keel (K) or the ship’s baseline.

3.1.11 weigh; to weigh, v—as commonly understood in everyday usage and in the maritime industry, and as used throughout this guide, means to determine by measuring the mass of.

3.1.12 weight, n—as commonly understood in everyday usage and in the maritime industry, and as used throughout this guide, is synonymous with mass. In this guide, weight in inch-pound units is measured in pounds and in long tons of 2240 lbs; and in SI units (metric), weight is measured in kilograms and in metric tons of 100 kg. Refer to Practice F 1332 for conversion factors to convert inch-pound quantities to SI (metric) quantities for units of weight, moment, moments to trim, and so forth.

3.1.13 weight classification, n—the system used in light ship weight estimating for grouping materials, equipment, or components of the ship in a structured order to facilitate comparison and to ensure completeness.

3.1.14 weight group, n—one of the three major elements of light ship weight as used in the weight classification, that is, hull structure, outfit, and machinery.

4. Summary of Guide

4.1 Determination of Weight and Moment Data—The weight and moment data for all components and material and their overall effect on the ship’s weight, center of gravity, list, and trim should be determined. As ship design or ship construction drawings are prepared and as material is selected, acquired, or received, the weight and centers of gravity of all items that comprise the ship should be determined and reported in the weight estimates and reports. These data may be obtained by estimation or calculation during preliminary and contract design, by a combination of estimation or calculation of ship construction drawings, and by actual weight determination of items during detail design and construction.

4.2 Weight Reporting and Control—The procedures for weight reporting and control, regardless of the level of reporting, are described in Section 6 and apply for commercial ships. The method and frequency of weight reporting can vary depending on the specific ship design, as well as the technical requirements set forth in the contract. The extent and level of weight control also can vary depending on the specific ship design. Although the weight control technical requirements for commercial ships usually are less demanding than those for U.S. Navy surface ships, the need for a mechanism to control the weight of a ship still exists. Sections S1 – S4 describe the specific weight control technical requirements for U.S. Navy surface ships.

5. Significance and Use

5.1 It is important to know the amount of weight and its location before the ship is built to be sure that when it is built it will have positive stability. Only through detailed weight estimating in the design stage and during construction can one be ensured that positive stability will be achieved and retained.

6. Procedure

6.1 A specified number of calendar days, that is, 30, 45, 60, or 90 after date of award, as specified by the owner, the shipbuilder should submit for agreement an independent weight and center of gravity estimate. This estimate should describe the weight and centers of gravity of the ship in comprehensive detail and should include summaries and work sheets showing the detailed work performed, for example, calculations and estimates based on the design information, drawings, specification, and so forth. Appendix X1 contains suggested forms for the independent estimate, and it includes a suggested weight classification system for the estimate. Terms used in the weight classification are defined in the Maritime Administration Publication, Classification of Merchant Ship Weights.3

6.2 A mutual agreement between the shipbuilder and the owner on the light ship weight and centers of gravity should be reached as quickly as possible after award of the shipbuilding contract. Agreement action should consist of a review of shipbuilder’s independent weight and center of gravity estimates and comparison with the owner’s estimate. Upon resolution of differences, an agreed upon weight and center of gravity estimate will result. Thereafter, the shipbuilder should be responsible for obtaining in the completed vessel the agreed upon weight and center of gravity characteristics adjusted for authorized departures from the contracted ship design, reflected in the agreed upon estimate.

6.3 Departures from the contracted ship design, reflected in the agreed upon estimate, which affect the light ship weight and centers of gravity, should not be undertaken until the shipbuilder has submitted to the owner his estimate of the effect on weight and centers of gravity of the ship and obtained written approval to proceed with the department. Departures, which have a total impact on any weight group of less than a specified percentage, that is, 0.01, 0.02, 0.03, or 0.04 % of the light ship weight, may be considered negligible and will not require written approval with respect to weight.

6.4 The shipbuilder should submit periodically, as agreed upon, to the owner, a tabulation of approved departures and their cumulative effect on weight and centers of gravity of the agreed light ship estimate. In addition, when submitting plans that involve departures from the type of construction in the contracted ship design, reflected in the estimate, the shipbuilder should itemize such departures and their effect on light ship weight and centers of gravity in his periodic reports. A final report should be submitted at the time of delivery adjusted to bring the estimated light ship weight and centers of gravity into reasonable agreement with the inclining experiment results.

7. Keywords

7.1 light ship; ship acquisition; weight control; weight estimate; weight report

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or purchase order. These requirements normally are invoked for U.S. Navy Surface Ships.

S1. SPECIAL GOVERNMENT REQUIREMENTS

S1.1 Government Documents, Drawings, and Publications—The following government documents, drawings, and publications form a part of this guide to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

S1.1.1 Naval Sea Systems Command (NAVSEA) Documents:
- 0900-LP-039-9020 Ship Work Breakdown Structure for Nuclear Propulsion Plant (U)\(^4\)
- S9040-AA-IDX-010/SWBS 5D, Expanded Ship Work Breakdown Structure, Vol I\(^5\)
- S9040-AA-IDX-020/SWBS 5D, Expanded Ship Work Breakdown Structure, Vol II\(^5\)

S1.2 Nongovernment Publications—The following document(s) form a part of this guide to the extent specified herein. Unless otherwise specified, the issues of the documents, which are DOD adopted, are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see S4.1).

S1.2.1 ANSI Document:\(^6\)
- X3.4 Code for Information Interchange

Note S1—Nongovernment standards and other publications normally are available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.

S1.3 Order of Precedence—In the event of a conflict between the text of this guide and the references cited herein, the text of this guide takes precedence. Nothing in this guide, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

S2. TERMINOLOGY

S2.1 accepted ship report (ASR), \(n\)—the ASR is the document that demonstrates the contractor’s performance with regard to weight control. The ASR highlights the differences between the accepted weight estimate (AWE) or the allocated baseline weight estimate (ABWE) and the delivered ship as inclined.

S2.2 accepted weight estimate (AWE), \(n\)—the AWE defines the weight and centers of gravity of a ship that was awarded under a specification-type contract using the information that was available at the time of contract award. It establishes contractual values for weight and KG and is the baseline for detail design and construction.

S2.3 acquisition margins, \(n\)—acquisition margins are weight and KG allowances included in the weight estimate to cover the inherent limits of precision and the undefined variations of component weight and centers of gravity that take place throughout the design phases and during the construction of a ship. To provide for adequate weight control and configuration control, acquisition margins are divided into five accounts: preliminary design margin, contract design margin, detail design and building margin, contract modification margin, and government-furnished material (GFM) margin.

S2.4 actual weight, \(n\)—actual weight is the value obtained by a measurement of material on an accurate scale or other weighing device.

S2.5 allocated baseline weight estimate (ABWE), \(n\)—the ABWE is the contractor’s definition of the weight and centers of gravity of a ship that was awarded under a performance-type contract at the time of hull and propulsion configuration approval. It is the baseline for detail design and construction.

S2.6 baseline weight estimate (BWE), \(n\)—the BWE is any designated weight estimate that is used as a starting point in a design phase for comparative analysis with subsequent weight estimates. Before contract award, the final estimate of each design phase is usually the baseline estimate for the succeeding phase. After contract award, the AWE or ABWE usually is the baseline estimate for the remainder of detail design and construction.

S2.7 bidder’s independent weight estimate (BIWE), \(n\)—the bidder’s (or offeror’s) independent weight estimate is prepared by each potential contractor in response to a solicitation. It is the bidder’s evaluation of the ship design based on the ship specifications, drawings, and data that comprise the contract package.

S2.8 calculated weight, \(n\)—calculated weight is weight computed from ship construction drawings and vendor drawings.

S2.9 capacity load condition (Condition E), \(n\)—the capacity load condition is the ship complete and ready for service in every respect. It is light ship (Condition A) plus the following variable loads: maximum number of officers, crew, and passengers that can be accommodated and their effects; maximum stowage of ammunition in magazines and ready service spaces; full allowance of aircraft and vehicles (fully fueled with full allowance of repair parts and stores); maximum amount of provisions and stores that can be carried in the assigned spaces; and maximum capacity of liquids in tanks. Fuel and lube oil shall be not greater than 95% of tank capacity, unless such tanks are compensating. Compensating tanks shall be considered filled with 95% fuel and 5% salt water. Maximum amounts of cargo and supplies, other than for ship’s own use,

\(^4\) Available from the Navy Ships Parts Control Center (SPCC), Code 709 Mechanicsburg, PA 17055.
\(^5\) Available from Naval Sea Logistics Center, Code 623, PO Box 2060, Mechanicsburg, PA 17055-0795.
\(^6\) Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
shall be included to the full capacity of the assigned spaces. This load condition shall be not greater than the limiting drafts.

S2.10 category, n—category is a fundamental unit of machinery weight classification for nuclear-propelled ships in accordance with NAVSEA 0900-LP-039-9020.

S2.11 category system, n—category system is a system of machinery weight classification for nuclear-propelled ships in accordance with NAVSEA 0900-LP-039-9020.

S2.12 contract data requirements list (CDRL) (DD Form 1423), n—a CDRL is a contract form listing all data items selected from an authorized data list to be delivered under the contract. It includes the format, content, frequency, submittal, and distribution requirements.

S2.13 contract design margin, n—the contract design margin is a weight and KG allowance included in the weight estimate to account for increases associated with design development during the contract design phase. This margin is included in the feasibility and preliminary design phases. No portion of this margin is consumed before the start of contract design.

S2.14 contract design weight estimates (CDWE), n—the CDWE is the weight estimate of the light ship, full load, and any other specified loading condition prepared during the contract design phase.

S2.15 contract modification margin, n—the contract modification margin is a weight and KG allowance included in the weight estimates and reports to account for increases associated with contract modifications issued during the detail design and construction phase. This margin is included in the feasibility, preliminary, and contract design phases. For performance-type contracts, this margin is also included in detail design and building phase. No portion of this margin is consumed before award of the detail design and construction contract.

S2.16 contract modification summary, n—the contract modification summary is a complete listing of the weight and moment effects of approved contract changes. This information is included as an appendix to the quarterly weight reports, the accepted ship report, and the final weight report.

S2.17 contractor-responsible condition, n—the contractor-responsible condition is the full-load condition without the effects of contract modifications, changes in GFM, and other allowable changes after the establishment of the AWE or ABWE. This condition is used to measure the contractor’s progress in achieving his requirement to deliver the ship within contractual values (see S3.3.4.6).

S2.18 current weight, n—current weight consists of the most accurate data available on the date of a given weight estimate or report. The summary of current weight is frequently a combination of estimated, calculated, and actual values.

S2.19 design and weight data sheet, n—the design and weight data sheet is a one-page summary that includes group level weight data, hull characteristics data, displacement, and stability characteristics data, load data, and machinery data.

S2.20 detail design and building margin, n—detail design and building margin is a weight and KG allowance included in the weight estimates and reports to account for design changes as a result of ship construction drawing development; growth of contractor-furnished material; omissions and errors in the AWE or ABWE, as well as differing shipbuilding practices, omissions and errors in the ship construction drawings; unknown mill tolerances; outfitting details; variations between the actual ship and its curves of form; and similar differences. This margin is to compensate for all contractor-responsible differences between the AWE or ABWE and the results of the inclining experiment, as well as tolerances for experimental variation in the inclining experiment. This weight and KG allowance is budgeted and included in the feasibility, preliminary, and contract design phases, but no portion of this margin is to be consumed before award of the detail design and construction contract. Values for these margins are to be selected by the offeror and included along with rationale for their basis in BIWEs or PABWEs. The final margin allowances are then subject to negotiation between the government and the contractor that was selected for detail design and construction.

The design and building weight margin shall be located at the same center of gravity as the summation of weight groups one through seven.

S2.21 electronic media, n—electronic media is used to transfer detailed weight and moment data that complies with the Navy standard weight estimate format and is used by NAVSEA to prepare Navy weight estimates and reports (see Annex A1).

S2.22 estimated weight, n—estimated weight is based on preliminary data and is subject to revision when more accurate information is available, such as when more detailed drawings are developed or when components are actually weighed.

S2.23 expanded ship work breakdown structure (ESWBS), n—ESWBS is a five-digit functional classification system in accordance with NAVSEA S9040-AA-IDX-010/SWBS 5D and S9040-AA-IDX-020/SWBS 5D (Vol I and II). For weight reporting purposes, only the first three digits of this system apply. The fourth and fifth single digit classification levels are used to incorporate the functions that support maintenance and repair needs.

S2.24 feasibility study weight estimate, n—the feasibility study weight estimate is a compilation of the ship’s weight and center of gravity data that result in light ship, full load, and any other specified loading conditions. This estimate is prepared during the feasibility study design phase.

S2.25 final weight report (FWR), n—a FWR is a detailed final report of weight and moment data for all required loading conditions. This report accurately reflects accumulated values for estimated, calculated, and actual weight data for the detail design, including the net effect of changes to GFM and adjudicated and unadjudicated contract modifications.

S2.26 full load condition (Condition D), n—the full-load condition is the ship complete and ready for service in every respect. It is light ship (Condition A), plus the following variable loads: authorized complement of officers, crew, and passengers and their effects; full allowances of ammunition in magazines and ready service spaces; full allowance of aircraft and vehicles (fully fueled with full allowance of repair parts and stores); full supply of provisions and stores for the periods specified in the design characteristics; full potable water tanks;
lube oil tanks to 95% of capacity; fuel tanks to 95% capacity, or in the case of compensating tanks, 95% fuel and 5% salt water; sewage collecting, holding, and transfer tanks to 25% capacity; anti-roll tanks to operating levels; and all other liquids in tanks to required capacity in accordance with characteristics and liquid-loading instructions. The ammunition, stores, fuel, and other liquids referred to previously are for the ship’s own use. Cargo (liquid and solid) is included in the amounts normally carried or to the specified portion of the full capacity of the assigned spaces.

S2.27 government-furnished material (GFM) margin, n—the GFM margin is a weight and KG allowance included in the weight estimates and reports to account for increases caused by the growth in GFM during the detail design and construction phase. This margin is included in the feasibility, preliminary, and contract design phases. For performance-type contracts, this margin is also included in detail design and building phase. No portion of this margin is consumed before award of the detail design and construction contract.

S2.28 government-furnished material summary, n—the GFM summary is a complete listing of weight and center of gravity data for material and equipment that will be provided by the government. The baseline GFM summary, which is included as part of the AWE or ABWE, reflects the Schedule A portion of the contract at the time of contract award. The GFM summary is continuously updated as the detail design weight estimates mature and the Schedule A is modified. Also, where the contract permits, the GFM summary can include other government-responsible equipment, such as equipment designated as standard for the class, directed procurement, and so forth.

S2.29 group, n—group is a fundamental unit of ship classification, identified by one numeric digit or an alphabetic designator. For weight estimates and reports, a group is the first character of the three-digit system. The summation of weights and moments for all of the three-digit elements that begin with the number one is the total for Group one, and similarly for the other groups.

S2.30 gyrodus, n—the gyrodus for roll, pitch, or yaw is the square root of the quotient of the ship’s weight moment of inertia about the roll, pitch, and yaw axes, respectively, divided by the ship’s displacement.

S2.31 inch-pound units, n—inch-pound units comprise a system of units using pounds, long tons, ft, ft-lbs, and ft-tons for reporting mass properties data. These weight and moment data are carried to the nearest pound and ft-lb at all detail levels. In addition, summaries are converted and reported to the nearest one-hundredth of a long ton and to the nearest ft-ton. All levers are carried to the nearest one-hundredth of a foot.

S2.32 KG, n—KG is defined as the height of the ship’s vertical center of gravity as measured from the bottom of the keel (includes keel thickness). When using SI units, care must be taken not to confuse the naval architectural symbol KG, in uppercase letters, with the SI symbol, kg, in lowercase letters (which represents the SI unit kilogram).

S2.33 light ship condition (Condition A), n—the light ship condition is the ship complete, ready for service in every respect, including permanent solid and liquid ballast, onboard repair parts, and liquids in machinery at operating levels, without any items of variable load.

S2.34 longitudinal lever, n—the longitudinal lever is the perpendicular distance from a transverse plane through the ship’s longitudinal reference to the center of gravity of an item. The longitudinal reference is located at the forward perpendicular, unless otherwise specified by the design contract or Ship Specification Section 096.

S2.35 mass properties data, n—mass properties data are those physical characteristics that define the magnitude, location, and distribution of weight in the ship. They include weight, centers of gravity location, moments, and weight moments of inertia.

S2.36 metric units, n—metric units comprise a system of basic measures that are defined by the International System of Units based on “Le Systeme International d’Unites (SI)” of the International Bureau of Weights and Measures.

S2.37 moment, n—a moment is the product of a weight and its lever. For example, the longitudinal moment of an item is the product of the weight of the item multiplied by its longitudinal lever.

S2.38 percent completion, n—percent completion is the ratio of the current weight, less the current estimated weight, to the current weight, expressed as a percentage.

S2.39 performance-type contract, n—a performance-type contract is the vehicle for ship acquisition resulting from a description of operational and mission requirements. Since the shipbuilder usually has substantial latitude in determining ship size and configuration, a PABWE or ABWE is used in this situation.

S2.40 pitch moment of inertia, n—moment of inertia about the transverse axis through the ship’s center of gravity.

S2.41 preliminary allocated baseline weight estimate (PABWE), n—the PABWE is the potential bidder’s (or offeror’s) estimate of the weight and center of gravity of the ship in response to a solicitation for a performance-type contract.

S2.42 preliminary design margin, n—preliminary design margin is a weight and KG allowance included in the weight estimates to account for increases associated with design development during the preliminary design phase. This margin is included in the feasibility design phase. No portion of this margin is consumed before the start of preliminary design.

S2.43 preliminary design weight estimate, n—preliminary design weight estimate is the weight estimate of the light ship, full load, and any other specified load condition prepared during the preliminary design phase.

S2.44 quarterly weight report (QWR), n—a QWR is a periodic assessment of displacement, drafts, trim, list, GM, and KG as the weight estimate matures during detail design and construction.

S2.45 roll moment of inertia, n—moment of inertia about the longitudinal axis through the ship’s center of gravity.

S2.46 service life allowances, n—service life allowances are weight and KG budgets included in the design to accommodate changes as a result of both authorized (for example, ship alterations) and unplanned growth (for example, paint,
personal belongings, and so forth) during the ship’s operational lifetime, which tends to increase displacement and impact stability.

S2.47 SI units (International System of Units), n—SI units (see Practice F 1332) comprise a system of units using kilograms (kg), metric tons, metres (m), kg/m, and metric ton-m for reporting mass properties data. All levers are carried to the nearest one-hundredth of a m. The weight and moment data are carried to the nearest kg and kg/m at all detail levels. In addition, summaries are converted and reported to the nearest one-hundredth of a metric ton and to the nearest metric ton-m.

S2.48 specification-type contract, n—a specification-type contract is the vehicle for ship acquisition resulting from a Navy controlled contract design. The products of the contract design, which usually become part of the shipbuilding contract and therefore the basis for the BIWE, include items such as: midship section drawing, lines drawing, table of offsets, general arrangement drawings, the shipbuilding specifications, and special requirements like not-to-exceed weight and KG values.

S2.49 standard longitudinal station breakdown, n—the standard longitudinal station breakdown is a system consisting of 22 stations designated by the letters A through X (excluding I and O). Station A is the only station forward of the forward perpendicular (FP). Station X is the only station aft of the aft perpendicular (AP). Stations B through W extend from the FP to the AP, and each comprises 1/20 of the length between perpendiculars.

S2.50 three-digit system, n—The three-digit system is a means of classifying mass properties data in a structured order. Every item that comprises the completed ship is included in the weight estimates and reports grouped in accordance with the three-digit system. Unless otherwise specified, the three-digit system for weight estimates and reports is the same as the first three digits of the ESWBS. An example of this numerical ordering is shown in Fig. S2.1.

S2.51 transverse lever, n—transverse lever is the perpendicular distance from the vertical centerline plane of the ship to the center of gravity of an item.

S2.52 vertical lever, n—vertical lever is the perpendicular distance from a horizontal plane through the molded baseline of the ship to the center of gravity of an item.

S2.53 weight control, n—weight control is all of the necessary actions, such as predicting, estimating, calculating, weighing, reporting, analyzing, evaluating, and reversing adverse trends to ensure that a ship’s weight and moments are consistent with its naval architectural limits for displacement, strength, stability, list, trim, and performance, such as speed, endurance, and seakeeping.
S2.54 weight control plan, n—a weight control plan outlines the procedures that will be followed to meet contractual weight control responsibilities (see S3.3.3.5).

S2.55 weight distribution, n—a weight distribution is a weight summary by the standard longitudinal station breakdown and is used to develop shear forces and bending moments.

S2.56 weight moment of inertia, n—weight moment of inertia about any reference axis through the ship’s center of gravity is the summation of the moment of inertia of each item about its own axis (parallel to the reference inertia axis), plus the products obtained by multiplying the weight of each item by the square of its distance from the reference inertia axis (see S3.3.2.3).

S2.57 weight reporting, n—weight reporting is the preparation and submission of the most accurate and current weight and moment data available at designated intervals throughout the design and construction phases.

S2.58 yaw moment of inertia, n—moment of inertia about the vertical axis through the ship’s center of gravity.

S3. PROCEDURES

S3.1 General Report Requirements—The contract will invoke this guide and specify technical data to be prepared, including modifications and exceptions. The CDRL will specify requirements for deliverables, such as data to be submitted, frequency of submission, number of copies, and recipients. The general requirements for the weight estimates and reports listed in this standard are specified in S3.1.1 through S3.2. The interface of weight estimates and reports is depicted in Fig. S3.1.

S3.1.1 Loading Conditions—Weight estimates and reports shall contain loading conditions for light ship, full load, and contractor responsibility, unless otherwise specified by the contract. The light ship condition includes a summary of one-digit groups and the remaining acquisition margin. These values are combined to result in the light ship weight, centers of gravity, and associated moments. The light ship condition in the FWR shall be adjusted to correlate with inclining experiment data. Building margin is used to account for irreconcilable differences between the FWR and the inclining experiment. Building margin is the only acquisition margin account that is permitted in the FWR. Other margin accounts, such as detail design margin, will either be fully depleted or if remainders exist they should be deleted from the FWR. The full-load condition is computed by adding specified items of variable load to the light ship condition and reflects the actual ship that is planned for delivery. The contractor-responsible condition is the full-load condition without the effect of contract modifications, both adjudicated and unadjudicated; the net weight change and associated moment changes from baseline values of current GFM items that were included in the original Schedule A or were subsequently added to Schedule A through a change in acquisition responsibility; and other
allowable changes beyond the control of the contractor (see S3.3.4.6). This condition is used to assess contractual performance. In addition to the total weight, centers of gravity, and associated moments, each loading condition also shall display KG, metacentric height (uncorrected and corrected for the free surface effect of liquids in tanks), list, trim, and drafts above the bottom of the keel at the perpendiculars and midship. Figs. S3.2-S3.4 provide examples of typical loading conditions.

S3.1.2 Margins—Acquisition margins shall be included in the estimates and reports. Throughout the design cycle, the appropriate margin account shall be adjusted concurrently to compensate for departures from the original estimates. This computation permits the maintenance of a constant design baseline until the budgeted margin account is exceeded. Weight margins shall be located at the same centers of gravity as the ESWBS current one-digit totals. Fig. S3.5 provides a typical example.

S3.1.3 Reasons for Changes—Weight estimates and reports shall include an addendum that explains each cause of significant change in weight or moment within every three-digit element. Unless otherwise specified, a significant change is a 1% or greater difference from an element’s previous estimate. A brief narrative of the ship’s condition relative to its naval architectural or contractual limits shall be included in this section. If any of these limits is in jeopardy, recommendations for reversing the adverse trend are also required.

S3.1.4 Table of Contents—The estimates and reports shall contain a table of contents.

S3.1.5 Special Coding—An explanatory note and remarks section shall be included to define special coding symbols, such as material codes, GFM indicators, and reasons for change indicators.

S3.1.6 Lever Symbol—Vertical levers shall be indicated by a “−” for below the baseline and a “+” or a blank for above the baseline. Longitudinal levers shall be indicated by an “F” or a “−” for forward of the reference plane and an “A,” a “+,” or a blank for aft of the reference plane. Transverse levers shall be indicated by a “P,” a “+,” or a blank for port and an “S” or a “−” for starboard.

S3.1.7 Reporting System Units—Estimates, reports, and other specified mass properties documentation and data shall be reported in either inch-pound or metric units as specified in the contract.

S3.1.8 Paper—Estimates and reports shall be machine written on 8 1/2- by 11-in. paper, and protected by hard covers, but not permanently bound. The original or reproducible copy shall be suitable for microfilming.

S3.1.9 Supporting Documents—Background information, studies, directives, correspondence, and all detail calculations pertaining to weight and moment data, including density factors, shall be made available to the Navy upon request.

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**FIG. S3.2 Example of Light Ship Condition Format**

<table>
<thead>
<tr>
<th>UNCLASSIFIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHIP U.S.S. SAMPLE</td>
</tr>
<tr>
<td>PREPARED BY 55W2</td>
</tr>
</tbody>
</table>

**WEIGHT AND MOMENT ESTIMATE**

<table>
<thead>
<tr>
<th>PERCENT COMPLETE</th>
<th>CURRENT VERTICAL</th>
<th>LONGITUDINAL TRANSVERSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EST. CALC. ACTUAL</td>
<td>WEIGHT VCG</td>
<td>MOMENT LCG $</td>
</tr>
</tbody>
</table>

| GROUPS 1 - 7 | WEIGHT VCG | 100.0 0.0 0.0 6608.29 26.68 716303.22934A1515922.0025 -111. |
|--------------|-------------|------------------|-----------------|---------------------|
| M MARGINS    | WEIGHT VCG | 100.0 0.0 0.0 264.33 26.68 7051229.34A60621.0025 -4. |
| L LOADS      | 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 |
| LIGHT SHIP CONDITION | 0.00 0.00 0.00 6872.62 27.75 190609229.34A1576143.0025 -116. |

**NOTE:** All of the following quantities (except as noted) are referenced from 250.00 FEET FWD OF THE MID PERPENDICULAR, THE CENTER LINE, AND THE BASE LINE.  

1. LENGTH BETWEEN PERPENDICULARS 500.00 FEET  
2. BOTTOM OF KEEL BELOW BASE LINE 0.06 FEET  
3. C.G. ABOVE BOTTOM OF KEEL 27.81 FEET  
4. C.G. ABOVE BASE LINE 27.75 FEET  
5. DRAFT AT L.C.F. FOR ABOVE DISP. 17.98 FEET  
6. TONS PER INCH IMMERSION 48.55 TONS/INCH  
7. TRANSVERSE METACENTER (KEEL) 28.80 FEET  
8. GM, WITHOUT FREE SURFACE Corr. 0.99 FEET  
9. FREE SURFACE CORRECTION 0.00 FEET  
10. GM, WITH FREE SURFACE CORR. 0.99 FEET  
11. MOMENT TO ALTER HEEL ONE DEGREE 119.20 FOOT-TONS  
12. LIST 0.97 DEGREES STBD  
13. MOMENT TO ALTER TRIM ONE INCH 1283.88 FOOT-TONS  
14. L.C.G. ON EVEN KEEL AT AFT DRAFT 246.93 FEET AFT  
15. LONGITUDINAL CENTER OF GRAVITY 229.34 FEET AFT  
16. TRIMMING LEVER 17.59 FEET FWD  
17. TRIM 7.85 FEET BY HEAD  
18. L.C.F. 270.77 FEET AFT  
19. DIFF IN DRAFT, L.C.F. TO MIDSHIP 0.35 FEET INCREASE  
20. DRAFTS: 22.24 FEET  
21. DESIGNED DRAG 0.00 FEET  

**UNCLASSIFIED**

*Note:* Inch-pound units are shown in example; however SI units are applicable when specified.
S3.2 Classified Reports—Weight reports containing classified data shall be marked in accordance with the security requirements contained in the contract. Whenever possible, classified or proprietary material shall be downgraded by deleting classified or proprietary portions that do not impair the usefulness of the document.

S3.3 Detailed Requirements:

S3.3.1 Predetail Design Phase—Estimates, reports, and supplemental documents for these design phases shall be prepared in accordance with S3.3.1.1 through S3.3.2.10, as applicable, unless otherwise specified.

S3.3.1.1 Weight Estimates and Reports—Weight estimates and reports prepared during these phases consist of baseline weight estimates, interim reports, and final design weight estimates. These estimates and reports contain detailed information appropriate to the design phase, loading conditions for light ship and full load, and are summarized in tabular form as follows:

(a) Three-digit system number and title.
(b) Current weight.
(c) Current vertical lever.
(d) Current vertical moment.
(e) Current longitudinal lever.
(f) Current longitudinal moment.
(g) Current transverse lever.
(h) Current transverse moment.

The mass properties data included in these estimates and reports are based on the engineering products available before the date of the document.

S3.3.1.2 Baseline Weight Estimates—The initial estimate for a given design phase is designated the baseline weight estimate. The baseline weight estimate consists of the light ship, full load, and any other specified loading condition. The estimate shall be titled Baseline Preliminary or Baseline Contract Design Weight Estimate. The requirements for the estimate are as specified in S3.3.1.1.

S3.3.1.3 Interim Reports—Weight estimates produced at specified intervals during a given design phase are designated interim weight reports. The interim report summarizes the current weight and moment status of the design and highlights any changes that occurred during the reporting period. The report shall contain the light ship, full load, and any other specified loading condition. It also shall reflect the appropriate title, such as Preliminary Design Interim Report No. 2. Fig. S3.6 and Fig. S3.7 provide typical examples. In addition to the requirements specified in S3.3.1.1, the report shall contain the following:

(a) Previous design phase group level summary.
(b) Previous report group level summary.
(c) Current group level estimate, and when required, the element level estimate and longitudinal weight distribution data.
(d) Net change, by group and total, between (a) and (c).

(e) Net change, by group and total, between (b) and (c).

(f) The current status of margins, loads, full-load displacement, KG, list, and trim. The changes corresponding to the total net change calculated for (d) and (e) shall be shown for margins, loads, and full-load displacement.

(g) A brief narrative providing rationale for any significant changes since the previous report and classified by the groups in which the changes occurred.

S3.3.1.4 Final Design Weight Estimate—The final estimate produced during a design phase is designated as the final design weight estimate. This estimate will reflect the final weight and moment data for light ship, full load, and any other specified loading condition. The estimate shall be titled Final Preliminary or Final Contract Design Weight Estimate. The requirements for the estimate are specified in S3.3.1.1 and S3.3.1.3.

S3.3.2 Supplemental Documents—The supplemental documents specified in S3.3.2.1 through S3.3.2.10 shall provide additional information and background data required during the preliminary/contract design phases.

S3.3.2.1 Weight and Moment Trade-Off Studies—These studies consist of determining the mass properties impact of various configuration change proposals and engineering alternatives that are being considered for inclusion in the design. The studies are delivered on an “as requested” basis and contain detailed mass properties calculations that define the impact of the study on ship displacement, KG, list, and trim. There is no fixed format for the completed study, but the ESWBS classification system shall be used to structure and summarize the data.

S3.3.2.2 Weight Distribution Report—A longitudinal weight distribution shall be provided in a tabulated format in accordance with the standard longitudinal station breakdown. Weight and longitudinal center of gravity shall be determined for each ship station for both light ship and full-load condition. The resultant total weight and longitudinal center of gravity for the weight distribution report for each condition shall equal the values reflected in the weight estimate or report for the same condition in that reporting period.

S3.3.2.3 Weight Moment of Inertia—When specifically required by the contract, weight moment of inertia data shall be included for the full-load condition. Current weights, centers of gravity, and engineering information describing the shape and orientation of each data element shall be used to develop weight moment of inertia data. The minimum data required are as follows:

(a) Ship-oriented roll, pitch, and yaw weight moments of inertia about each individual data element’s centroidal axes.

(b) Ship-oriented roll, pitch, and yaw weight moments of inertia about the ship’s centroid in the full-load condition.
S3.3.2.4 Ship Specification Sections—Ship specification sections shall define the requirements of the weight control program and the range of acceptable trim and list limit values that are to be invoked upon the shipbuilder. Deviations from this standard, such as special loading conditions, reporting units, or margins, shall be defined clearly. The format for the specification sections will be provided by NAVSEA.

S3.3.2.5 Circular of Requirements Sections—These sections shall provide the weight control requirements when a performance-type contract is used. The content of these sections shall be similar to S3.3.2.4, with the addition of service-life allowance quantities.

S3.3.2.6 Contract Data Requirements List (CDRL)—A CDRL will be developed that itemizes the data deliverables that shall be required by the ship acquisition contract. The portion of the CDRL that contains weight estimates, reports, and supplemental documents shall be generated during the contract design phase (see S4.2).

S3.3.2.7 Solicitation Input—A request for proposals or similar document shall be prepared that describes the ship design to potential shipbuilders and defines the format for submitting a bid or making an offer. The following portions of the solicitation package that pertain to weight control shall be generated during contract design:

(a) Instructions to Offerors—This section describes the content of the weight control material that will be submitted for source selection consideration. The bidder’s Independent Weight Estimate or Preliminary Allocated Baseline Weight Estimate, Preliminary Weight Control Plan, and resumes of weight control personnel are typical examples.

(b) Factors for Determining Loads—These are allowances, densities, and stowage factors that are used in the variable load portion of the full-load condition are included in the solicitation to permit a consistent calculation of load items by the bidders or offerors.

(c) Weights for Schedule A Items—This listing establishes the baseline GFM weight that will be required in the AWE/ABWE.

S3.3.2.8 Weight Control Contract Clause—The contract clause for weight control shall be provided for inclusion in the shipbuilding contract. The clause shall contain Not-To-Exceed (NTE) displacement and KG values, when applicable; a requirement for adjudicating the weight and moment effect of contract changes; a requirement that GFM growth is to be agreed upon before the inclining experiment; an explanation of the contractor-responsible condition; the method of incorporating changes that are proposed solely to achieve satisfactory naval architectural characteristics; and the amount of liquidated damages that apply.

S3.3.2.9 Design Notebook—The design notebook shall include a completed set of weight data collection sheets. For each system, these sheets describe the composition of the system,
# USS SAMPLE WEIGHT AND C.G. DESIGN MARGIN STATUS
PRELIMINARY/CONTRACT DESIGN - INTERIM REPORT

## A. WEIGHT:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GROUPS 1-7</td>
<td>6084.9</td>
<td>6123.1</td>
<td>6148.4</td>
<td>(+) 63.5</td>
<td>(+) 25.3</td>
</tr>
<tr>
<td>2. a. P.D. Margin</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2. b. C.D. Margin</td>
<td>76.9</td>
<td>46.4</td>
<td>35.6</td>
<td>(-) 41.3</td>
<td>(-) 10.8</td>
</tr>
<tr>
<td>3. D &amp; B Margins</td>
<td>392.1</td>
<td>392.1</td>
<td>392.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4. Loads</td>
<td>1874.4</td>
<td>1870.9</td>
<td>1839.2</td>
<td>(-) 35.2</td>
<td>(-) 31.7</td>
</tr>
</tbody>
</table>

5. Projected Delivery 8428.3 8432.5 8415.3 (-) 13.0 (-) 17.2

6. Limits:
   - Speed                        9400
   - Strength                     9370
   - Subdivision "V" Lines        9426
   - 9500

**SERVICE LIFE DISPLACEMENT ALLOWANCE:**

7. Required 841
8. Available at Projected Delivery 955

## B. CENTER OF GRAVITY - CURRENT STATUS:

<table>
<thead>
<tr>
<th>Item</th>
<th>KG</th>
<th>List</th>
<th>Trim</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GROUPS 1-7</td>
<td>26.26</td>
<td>26.24</td>
<td>2.95° (P) 0.33° (A)</td>
</tr>
<tr>
<td>2. a. P.D. Margin</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>2. b. C.D. Margin</td>
<td>0.28</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>3. D &amp; B Margins</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

4. Projected Delivery (Light Ship) 27.54
5. Projected Delivery (Full Load) 23.96 0.37° (P) 0.77° (A)

**LIMITS:**

<table>
<thead>
<tr>
<th>Allowable KG</th>
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<th>Trim</th>
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</thead>
<tbody>
<tr>
<td>25.32</td>
<td>0.50° P/S 1.5°(A)/0.5°(F)</td>
<td></td>
</tr>
</tbody>
</table>

**SERVICE LIFE KG ALLOWANCE:**

6. Required 1.00
7. Available at Projected Delivery 1.36

Note: Inch-pound units are shown in example, however SI units are applicable when specified.
# USS SAMPLE WEIGHT AND C.G. DESIGN MARGIN STATUS
## PRELIMINARY/CONTRACT DESIGN - INTERIM REPORT

<table>
<thead>
<tr>
<th>Weight Group</th>
<th>Contract Design Baseline</th>
<th>Last Report</th>
<th>Current Report</th>
<th>Change From BL</th>
<th>Change Last Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Structure</td>
<td>2936.2</td>
<td>2932.5</td>
<td>2941.1</td>
<td>(+)12.2</td>
<td>(-)15.9</td>
</tr>
<tr>
<td>2. Propulsion</td>
<td>717.0</td>
<td>705.7</td>
<td>704.8</td>
<td>(-)9.7</td>
<td>(+)7.9</td>
</tr>
<tr>
<td>3. Elec. Plant</td>
<td>392.1</td>
<td>393.9</td>
<td>401.8</td>
<td>(+)9.7</td>
<td>(+)7.9</td>
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<tr>
<td>4. Command/Surv.</td>
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<td>381.7</td>
<td>381.7</td>
<td>(-)13.2</td>
<td>---</td>
</tr>
<tr>
<td>5. Aux. Systems</td>
<td>799.9</td>
<td>826.7</td>
<td>810.8</td>
<td>(+)10.9</td>
<td>(-)15.9</td>
</tr>
<tr>
<td>6. Outfit &amp; Furn.</td>
<td>554.4</td>
<td>583.8</td>
<td>609.4</td>
<td>(+)55.0</td>
<td>(+)25.6</td>
</tr>
<tr>
<td>7. Armament</td>
<td>300.4</td>
<td>298.8</td>
<td>298.9</td>
<td>(-)1.5</td>
<td>(+)0.1</td>
</tr>
<tr>
<td>Total Groups 1 thru 7:</td>
<td>6084.9</td>
<td>6123.1</td>
<td>6148.4</td>
<td>(+)63.5</td>
<td>(+)25.3</td>
</tr>
</tbody>
</table>

**COMMENTS:**

Note: Inch-pound units are shown in example, however SI units are applicable when specified.
the source of the mass properties data, the latitudes in the system definition that could cause weight variations, the parameters and assumptions that were used to generate the mass properties data, and the concurrence of the cognizant technical code. In addition to the weight data collection sheets, the design notebook shall include a record of the information that was used in the development of the estimates and reports. This information typically consists of engineers’ notes, memora- nanda, records of telephone conversations, margin determination/rationale, interim reports, material equipment lists, and an index of drawings, sketches, and reports that were translated into mass properties data. Separate notebooks are required for preliminary design and contract design.

S3.3.2.10 Design History—The design history is a combination of narrative and tabular data that summarizes in chronological order the mass properties evolution of the ship design. The text highlights the major problem areas and their resolutions during the design phase, significant issues and decisions that had an impact on mass properties, and a discussion of margin usage. The narrative is interspersed with summary data from the weight estimates and reports. Separate histories are required for preliminary design and contract design.

S3.3.3 Pre-Award Process—This process is the period between the release of the request for proposals (RFP) or request for bids and the award of the contract. Estimates and supplemental documents required during this process shall be in accordance with S3.3.3.1 through S3.3.3.2, as applicable.

S3.3.3.1 Weight Estimates—The BIWE or the PABWE is prepared during this process. The estimate shall contain detailed information appropriate to the design phase and loading conditions for light ship and full load and shall be summarized in tabular form as follows:

(a) Three-digit system number and title.
(b) Current weight.
(c) Current vertical lever.
(d) Current vertical moment.
(e) Current longitudinal lever.
(f) Current longitudinal moment.
(g) Current transverse lever.
(h) Current transverse moment.

When a technical evaluation is conducted during source selection, the estimate is reviewed for appropriate content and scored against the requirements. After contract award, the successful bidder’s, or offeror’s, estimate becomes the basis for the AWE or ABWE.

S3.3.3.2 Bidder’s Independent Weight Estimate (BIWE)—The BIWE establishes the potential contractor’s estimate of the ship design before contract award. It is based on the contract, ship specifications, all of the documents referenced therein, the factors for determining loads, and the weights for GFM. The BIWE shall conform to the content and format requirements of S3.3.3.1, include estimated values for design and building margin, and contain loading conditions for light ship and full load. The variable loads shall be realistically distributed throughout the ship in their appropriate spaces. The bidder, or offer, shall include in appendices the following information:

(a) Historical backup data for estimating factors that were used in the development of the BIWE, such as mill tolerance, paint, weld material, insulation, and so forth.
(b) The technical analysis that substantiates the values selected for design and building margin.
(c) A summary of GFM as reported in the details of the BIWE (see S3.3.3.1).

When NTE displacement and KG values are defined in the contract, the bidder, or offeror, shall take the appropriate measures to reflect the design solutions and building practices that ensure delivery of a satisfactory ship.

S3.3.3.3 Preliminary Allocated Baseline Weight Estimate (PABWE)—The PABWE establishes the potential contractor’s estimate of the ship design before the award of a performance-type contract. It is based on the contract, Circular of Requirements, all the documents referenced therein, and the bidder’s, or offeror’s, proposed hull and propulsion configurations. The report shall conform to the requirements of S3.3.3.1, include estimated values for design and building margin, and contain contract modification and GFM margins as specified. Variable loads shall be realistically distributed throughout the ship in their appropriate spaces. The bidder, or offeror, shall include in appendices the following information:

(a) Historical backup data for estimating factors that were used in the development of the PABWE, such as mill tolerance, paint, weld material, insulation, and so forth.
(b) The technical analysis that substantiates the values proposed for design and building margin.
(c) A summary of GFM as reported in the details of the PABWE (see S3.3.4.3).

After contract award, the PABWE of the successful bidder, or offeror, becomes the basis for the ABWE, which is used to measure contractor responsibility.

S3.3.3.4 Supplemental Documents—The supplemental documents specified in S3.3.3.5 and S3.3.3.6 provide additional information and background data required during the pre-award process.

S3.3.3.5 Preliminary Weight Control Plan—A preliminary weight control plan shall be submitted with detail design and construction proposals that outlines the procedures that shall be followed to meet contractual weight control responsibilities. The plan shall include, but is not limited to, the following topics:

(a) A discussion of design risk with respect to the ship’s naval architectural characteristics, including special weight control problems and the areas that will receive weight control emphasis.
(b) A discussion of the method to be used in adjusting margin accounts.
(c) The frequency of briefings to top management concerning the ship’s naval architectural condition throughout the detail design and construction phase. The individual who will give the briefings shall be identified.
(d) A description of the computer systems, both hardware and software, that will be used in the weight control effort.
(e) A listing of equipment that will be used to perform actual weight measurements. The listing shall include equipment capacity, accuracy tolerance, and calibration frequency.
S3.3.4.1 Weight Estimates and Reports—Weight estimates and reports prepared during this phase consist of the ABWE or AWE, QWR, and FWR. These estimates and reports shall contain detailed information appropriate to the status of the design at the time of submittal and loading conditions as described in S3.1.1, and shall be summarized in tabular form as follows:

(a) Three-digit system number and title.
(b) Original weight (not required for AWE or ABWE).
(c) Current weight.
(d) Current vertical lever.
(e) Current vertical moment.
(f) Current longitudinal lever.

g) Current longitudinal moment.
(h) Current transverse lever.
i) Current transverse moment.
j) Current percent completion (not required for AWE or ABWE).
k) Special coding symbols.

S3.3.4.2 Every item that comprises the completed ship shall be included in the weight estimates and reports and grouped in accordance with the three-digit system. For the data to be useful in a variety of applications, the details shall contain an accurate description that links each listed item to a recognizable component. For example, a long listing of plates, tees, angles, beams, chocks, and so forth, with precise weight and center of gravity data, does not comprise a satisfactory estimate, unless those pieces of structure can be readily identified with a specific bulkhead, deck, foundation, or other structure. Similarly, the descriptions for distributive systems shall indicate the major components that are being connected. Component descriptions shall include identifiers, such as type, size, rating, capacity, and so forth. An example of adequate detail and proper numerical ordering is shown in Fig. S2.1. Calculations and actual weight determinations shall be terminated in advance of report preparation to ensure timely submittals.

S3.3.4.3 Determination of Mass Properties Data—Mass properties data may be obtained by a combination of estimation or calculation of ship construction drawings and actual weight determination. The actual weight of all components and equipment, greater than 500 lbs or 225 kg (unless otherwise specified), both contractor and government-furnished, shall be determined through accurate scale weighing along with the estimation or calculation of centers of gravity. The actual weights for materials, components, and equipment, less than 500 lbs or 225 kg, shall be determined on a selective or sampling basis, as determined by the contractor, to provide unit weight data. Potential candidates for actual weight determination on a selective basis include such items as insulation, structural plates and shapes, sheathing, piping, and the components and equipment less than 500 lbs or 225 kg. Where factors or percentages are used, such as for estimating and calculating paint, mill tolerance, and welding, the contractor shall substantiate these values by supplying background information (current and historical). Historical background information on paint, mill tolerance, and welding factors shall be forwarded with the BIWE or PABWE. Final values for paint, mill tolerance, and welding factors, based on current ship information, shall be forwarded with the FWR. Also, when design development has occurred for a component, system, or portion of structure, a reevaluation of the original weight estimate shall be made to obtain the most accurate current weight. In addition, to minimize the amount of actual weight determination at the shipbuilding site, the contractor shall require, through acquisition documents, subcontractors or vendors to submit information on the current weight and center of gravity of all major assemblies, equipment, fittings, or components to be installed on the ship. It is suggested that information be submitted by subcontractors or vendors in the following sequence:
(a) An estimate of weight and center of gravity in the proposal.
(b) The calculated weight and center of gravity when the design is completed.
(c) The actual weight and calculated center of gravity when the fabrication or assembly is completed.
S3.3.4.4 Accepted Weight Estimate (AWE)—After contract award, the contractor and NAVSEA shall agree on AWE values for displacement and KG. To expedite this agreement, the contractor shall, upon request, visit NAVSEA not less than one month before the required submittal date of the AWE. The estimate shall consist of the contractor’s BIWE that was submitted during the solicitation process, adjusted as necessary to reflect corrections and negotiated changes, such as reclassification of data. The AWE shall include loading conditions, summaries, supporting details for each three-digit element, appropriate margins, and an appendix that establishes the baseline for measuring detail design changes in GFM. The estimate shall conform to the content and format requirements of S3.3.4.1.
S3.3.4.5 Allocated Baseline Weight Estimate (ABWE)—The ABWE establishes the contractor’s estimate of the ship design when the hull and propulsion configurations are defined. The ABWE shall reflect a design that meets all of the required performance criteria, satisfies the required service-life allowances, and includes the appropriate margins. The basis for the estimate shall be the contractor’s PABWE that was submitted during the solicitation process, adjusted as necessary to reflect design changes and corrections. The ABWE shall include loading conditions, summaries, margins, and an appendix that establishes the baseline for measuring detail design changes in GFM. The estimate shall conform to the content and format requirements of S3.3.4.1.
S3.3.4.6 Quarterly Weight Reports (QWR)—The QWR shall document the current mass properties status of the ship design and construction effort. The light ship and full-load conditions shall reflect the ship that is projected for delivery, including the current mass properties values for GFM and contract modifications, both adjudicated and unadjudicated. The contractor-responsible condition shall be used to adjust the current full load to account for changes that occur after the establishment of the contractual baseline and are not within the control of the shipbuilder. Examples of these types of changes are as follows:
(a) Changes in weight of GFM and the moment changes associated with those weight changes.
(b) The net effect of contract modifications.
(c) Changes in weight of equipment designated as standard for the class and the moment changes associated with those weight changes.
(d) Changes that result from the required use of warranted documentation.
(e) Growth resulting from directed acquisitions.
S3.3.4.7 Separate summaries for each type of change previously listed shall be provided as appendices to the QWR. A GFM summary (see S3.3.4.3) and a contract modification summary (see S3.3.4.17) are required with every submittal of a QWR. Other summaries may be submitted at the option of the contractor to substantiate growth beyond his control. If an optional summary is submitted, it shall document all of the activity for that particular type of change, weight increases and decreases, and modified locations. The ship’s displacement, KG, list, and trim from the contractor-responsible condition shall be compared to the AWE or ABWE values for displacement and KG and the specified allowable ranges for list and trim. Report details shall be grouped in accordance with the three-digit system, and each item shall indicate whether the information shown is estimated, calculated, or based on actual weight determination. The report shall conform to the content and format requirements of S3.3.4.1. In addition, the report shall contain reasons for changes, recommendations to correct any adverse trends, and a listing of all the equipment for which an actual weight determination was performed during the reporting period.
S3.3.4.8 Final Weight Report (FWR)—The FWR shall reflect the final status of the ship design and construction effort that resulted in a delivered product and is normally based on an inclining experiment. All of the reporting requirements of a QWR (see S3.3.4.6) also apply to a FWR. In addition, when inclining experiment full-load displacement and KG values differ from the weight estimate without margin predictions by greater than ½ %, an analysis of the data shall be conducted to reconcile the differences. Findings that result in correction of inaccuracies, reevaluation of factors, and so forth, shall be incorporated in the FWR. The only acquisition margin that may appear in the FWR is building margin. This margin accounts for irreconcilable differences between the weight report and the inclining experiment. The FWR shall contain a narrative that describes the portions of the weight data that are still based on factors, such as paint, weld material, mill tolerance, and so forth, and the criteria that comprise the factors.
S3.3.4.9 Weight Estimate and Report Appendices—The following appendices specified in S3.3.4.10 through S3.3.4.17 provide additional information and background data during the detail design phase.
S3.3.4.10 GFM Summary—The purpose of the GFM summary is to extract from the estimates and reports weight and location data for all GFM and identify the government responsible net weight and moment change that occurs to GFM during detail design. The GFM summaries shall accurately reflect the Schedule A portion of the contract, conform to the content and format requirements of S3.3.4.16, and be included as an appendix to the BIWE or PABWE, AWE or ABWE, each QWR, and the FWR. The baseline for measuring detail design changes is established in the AWE or ABWE. Once accepted, the baseline is only revised when acquisition responsibility is transferred or to correct data that was available to the contractor before the AWE or ABWE, but was inaccurately reported. Weight changes to GFM and the moment changes associated with those weight changes, along with contract modifications and other types of changes beyond the control of the shipbuilder, are deducted from the current full-load condition to arrive at the contractor-responsible condition. Changes to GFM can result from better definition of the baseline items as the
design matures; the addition, deletion, or modification of items by a revision to Schedule A; or a transfer of acquisition responsibility.

S3.3.4.11 Adjustment to Baseline GFM—The weight and moment totals from the GFM summary in the AWE or ABWE shall be the basis for measuring all subsequent GFM changes and shall be known as the baseline values. In cases in which inaccuracies are discovered in the baseline values for which correct data was available to the contractor before submittal of the AWE or ABWE, the weight report details shall be modified to reflect the correct information. In the GFM summary, the baseline values shall be adjusted and the weight and moment effect of the adjustment becomes the responsibility of the contractor. Fig. S3.8 provides a typical example of the accounting procedure for this type of change.

S3.3.4.12 Design Development to Baseline GFM—When design development occurs to items of baseline GFM, the weight report details shall be updated to record current weight and moment data. The contractor is responsible for properly locating the items of GFM throughout detail design. Moment changes resulting from the relocation of GFM to suit design development are not allowable deductions when determining the contractor-responsible condition. The government is responsible for the weight and moment impact of weight changes to baseline items that occur after the establishment of the baseline. An acceptable method of computing government-responsible moment changes is to multiply the net weight change of baseline GFM design development by the centers of gravity from the original or adjusted baseline GFM. These net weight and moment changes are then deducted from the current full-load condition when determining the contractor-responsible condition. Additionally, once a contract modification has been adjudicated, the GFM portion of the change shall be incorporated into a second section of the GFM summary (conforming to the content and format requirements of S3.3.4.16, with the GFM weight and moment values included as adjudicated in the baseline weight column and in the current values. This section will be used to monitor weight changes to GFM after the contract modification has been adjudicated. Any weight and moment changes identified in GFM after adjudication shall be reflected in the current weight column and included with the weight and moment changes that are deducted from the current full-load condition when determining the contractor-responsible condition.

S3.3.4.13 Revision to Schedule A—When Schedule A is revised to add, delete, or modify GFM, the weight report shall be updated accordingly and the changes shall be reflected as current values in the GFM summary. Since these types of changes will usually be implemented by a contract modification, the contractor shall ensure that the weight and moment changes are also reflected in the contract modification summary. However, for the purpose of determining contractor responsibility, the weight and moment impact of contract modifications on GFM before adjudication should not be included with the GFM net changes, since it is already included with the net effect of contract modifications. Any changes in GFM included with contract modifications after adjudication are covered in S3.3.4.12.

S3.3.4.14 Acquisition Responsibility Changes from Government to Contractor—When acquisition responsibility passes from the government to the contractor, the current values and the baseline values for the item shall be deleted from the GFM summary. If the current weight differs from the baseline weight, the contract modification shall reflect the weight difference. Moment changes associated with the weight difference may be computed by using the baseline centers of gravity for the item that was transferred. After the modification has been adjudicated, changes in weight and location are the responsibility of the contractor.

S3.3.4.15 Acquisition Responsibility Changes from Contractor to Government—When acquisition responsibility passes from the contractor to the government, current weight and moment values for the item that appear in the most recently submitted weight report shall be added to the baseline weight and current weight columns of the GFM summary. Contract modifications that cause this type of transfer shall reflect no weight or moment change. Any subsequent weight change shall be treated as routine design development of GFM and becomes the responsibility of the government.

S3.3.4.16 GFM Summary Format—The GFM summary shall be in tabular form with subtotals by the three-digit system, grand totals for current values, and shall include columns containing the following information for each item:

(a) Three-digit system number.
(b) Schedule A item number.
(c) Description of the item.
(d) Baseline weight.
(e) Current estimated, calculated, or actual weight.
(f) Current vertical lever.
(g) Current vertical moment.
(h) Current longitudinal lever.
(i) Current longitudinal moment.
(j) Current transverse lever.
(k) Current transverse moment.

S3.3.4.17 Contract Modification Summary—Before each claim for equitable adjustment in price or delivery or both, asserted pursuant to the changes clause of the contract, an estimate of the net weight and moment change resulting from the contract modification shall be prepared and submitted to the supervisor. The contract modification summary shall reflect these weight and moment impacts as they appear in the details of the weight estimate, for both adjudicated and unadjudicated changes, including field changes. The summary shall consist of all approved changes listed numerically by NAVSEA number and shall include the title, net weight, and moment impact of each change; an identifier that indicates whether the data is adjudicated or unadjudicated; and a grand total representing the net effect of all approved contract modifications. The contract modification summary shall be submitted as an appendix to the QWRs, the ASR, and the FWR. Supporting details for each contract modification shall be incorporated into the body of the weight estimate as soon as the change is approved. Before adjudication of the contract modification, the weight and moment impact of the change as reported in the contract modification summary shall reflect the current values of the supporting details. After the contract modification has been
### GFM SUMMARY TOTALS

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>VCG</th>
<th>V. Moment</th>
<th>LCG</th>
<th>L. Moment</th>
<th>TCG</th>
<th>TM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Baseline Values from AWE/ABWE</td>
<td>355.00</td>
<td>31.22</td>
<td>11083</td>
<td>157.35A</td>
<td>55859</td>
<td>0.17P</td>
<td>60</td>
</tr>
<tr>
<td>Adjustments to Original Values (+/-)</td>
<td>+2.25</td>
<td>45.72</td>
<td>117</td>
<td>202.08A</td>
<td>515</td>
<td>9.27S</td>
<td>-24</td>
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<tr>
<td>New Basis for Measuring GFM Changes</td>
<td>357.25</td>
<td>31.35</td>
<td>11200</td>
<td>157.80A</td>
<td>56374</td>
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<tr>
<td>Current Values from Quarterly #</td>
<td>363.50</td>
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<td>11330</td>
<td>157.25A</td>
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<tr>
<td>Government-Responsible Change to GFM</td>
<td>+6.25</td>
<td>20.80</td>
<td>130</td>
<td>125.76A</td>
<td>786</td>
<td>1.28P</td>
<td>8</td>
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</table>

Note: Inch-pound units are shown. In example, however SI units are applicable when specified.

FIG. S3.8 Example of GFM Summary Format
adjudicated, the supporting details are treated as any other line items in the weight estimate, but the weight and moment effect of the change as reported in the contract modification summary remains at the adjudicated values. The weight and moment impact of the addition, deletion, or modification of GFM to the Schedule A is implemented by a contract modification summary. If acquisition responsibility passes from the government to the contractor, the contract modification summary shall reflect any difference in weight between the current and baseline weight values. Moment changes associated with the weight difference may be computed by using the baseline centers of gravity for the item that was transferred. Changes in weight are the responsibility of the contractor after the contract modification has been adjudicated. Contract modifications that change acquisition responsibility from the contractor to the government shall reflect no weight or moment impact in the contract modification summary.

S3.3.4.18 Supplemental Weight Report—The following supplemental weight report, specified in S3.3.4.19, provides additional information and background data during the detail design phase.

S3.3.4.19 Machinery Weight Report (Nuclear)—A machinery weight report for a nuclear ship design shall be submitted in the category system in accordance with NAVSEA 0900-LP-039-9020. The report shall be divided into two sections. Section I shall contain nuclear machinery items; Section II shall contain the remaining items of the category system. The following summary sheets shall be included:

(a) A listing of a total for each three-digit group within each of the Categories A through M (excluding I). Subtotals shall be listed for each category and a grand total for nuclear propulsion machinery.

(b) Same as (a), except that Sections I and II shall be listed separately with a subtotal for each section, and a grand total for nuclear propulsion machinery.

(c) A listing of a total of Categories A through M (excluding I) for each three-digit group to make a grand total for nuclear propulsion machinery.

The totals for all summaries shall be the same.

S3.3.4.20 Machinery Weight Report Format—The report shall include the following information in tabular form:

(a) Original weight values from the AWE or ABWE for each item.

(b) Current weight of each item.

(c) Current vertical levers.

(d) Current vertical moments.

(e) Current longitudinal levers.

(f) Current longitudinal moments.

(g) Current transverse levers.

(h) Current transverse moments.

When this report is submitted concurrently with the AWE or ABWE, the QWR, and the FWR, it shall reflect the details of the report it accompanies.

S3.3.5 Supplemental Documents—The following supplemental documents when required by the CDRL, provide additional information and background data during the detail design and construction phase.
**ACCEPTED SHIP REPORT**

<table>
<thead>
<tr>
<th></th>
<th>WEIGHT</th>
<th>KG</th>
<th>VERTICAL MOMENTS</th>
<th>LCG</th>
<th>LONGITUDINAL MOMENTS</th>
<th>TCG</th>
<th>TRANSVERSE MOMENTS</th>
<th>TRIM (F) / (A)</th>
<th>LIST (P) / (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclining Experiment (Condition A)</td>
<td></td>
<td></td>
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<tr>
<td>Current Loads from latest QWR (add)</td>
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<tr>
<td>Current Full Load (Total)</td>
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<tr>
<td>Net Effect of Contract Mods (Deduct) (note 1)</td>
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<tr>
<td>Directed Modifications to Loads (Deduct)</td>
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<tr>
<td>GFM Net Changes (Deduct) (note 2)</td>
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<tr>
<td>Other Allowable Adjustments (note 3)</td>
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<tr>
<td>Contractor Responsible Values (Total)</td>
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<tr>
<td>Accepted Weight Estimate Values</td>
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<td></td>
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<td></td>
<td>(note 4)</td>
<td>(note 4)</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Represents summation of adjudicated and unadjudicated values for all contract modifications that were included in the inclining experiment data (including those affecting variable loads).
2. Represents values for net weight and moment changes in GFM since the AWE.
3. These adjustments can include equipment designated as standard for the class changes, changes resulting from the required use of warranted documentation, or growth resulting from directed procurements.
4. Insert tolerances agreed to or limits in Section 070 of the Ship Specifications.

**FIG. S3.9 Example of Accepted Ship Report Format**
### ACCEPTED SHIP REPORT
(Performance-type contract)

<table>
<thead>
<tr>
<th></th>
<th>WEIGHT</th>
<th>KG</th>
<th>VERTICAL MOMENTS</th>
<th>LCG</th>
<th>LONGITUDINAL MOMENTS</th>
<th>TCG</th>
<th>TRANSVERSE MOMENTS</th>
<th>TRIM (F / (A)</th>
<th>LIST (P) / (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclining Experiment (Condition A)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Current Loads from latest QWR (add)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Current Full Load (Total)</td>
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<tr>
<td>Government Margins</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Contract Modifications Remaining (Add)</td>
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<tr>
<td>Exceeded (Deduct)</td>
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<td></td>
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<tr>
<td>GFM Remaining (Add)</td>
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<tr>
<td>Exceeded (Deduct)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Contractor Responsible Values (Total)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABWE/AWE Values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(note 1)</td>
<td>(note 1)</td>
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<tr>
<td>Governing NA Limit</td>
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<tr>
<td>Available Service Life Allowance</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required Service Life Allowance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** 1. Insert tolerances agreed to or limits in Section 070 of the Ship Specifications.

**FIG. S3.10 Example of Accepted Ship Report Format**
# DESIGN AND WEIGHT DATA SHEET

## USS SAMPLE

### General Data
- **Type:** 4000 miles
- **Endurance:** 4000 miles
- **Trial Speed:** 20.2 knots
- **Complement:** 300

### Hull Characteristics
- **LQA:** 583'3-13/16"
- **LBP:** 529'0"
- **MP:** 264/6"
- **Block Coef.:** 0.491
- **Midship Coef.:** 0.823
- **Waterplane Coef.:** 0.724
- **Volume of Superstructure:** 240,850 ft³

### Displacement and Stability Characteristics
- **Limiting Drafts:** 21'0"
- **Full Load Drafts:** Fwd 19.16', Aft 19.67', Mean 19.42'
- **Limiting KG:** 22.88 (Full Load Cond. D Basic Ship, No Margins)
- **Trim:** 0.51 by stern

### Inclining Experiment
- **Cond. A:** 5929.261, 7905.6
- **Cond. D:** 5929.261, 7905.6
- **KG:** 26.0, 26.2

### Weight Summary Data*

<table>
<thead>
<tr>
<th>Group</th>
<th>Wt (Tons)</th>
<th>VCG</th>
<th>LCG **</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hull Structure</td>
<td>3074.9</td>
<td>24.0</td>
<td>289.6</td>
</tr>
<tr>
<td>2. Propulsion</td>
<td>761.9</td>
<td>22.7</td>
<td>308.4</td>
</tr>
<tr>
<td>3. Electric Plant</td>
<td>284.7</td>
<td>28.1</td>
<td>289.9</td>
</tr>
<tr>
<td>4. Comm and Control</td>
<td>355.7</td>
<td>25.2</td>
<td>162.6</td>
</tr>
<tr>
<td>5. Auxiliary Systems</td>
<td>736.2</td>
<td>28.4</td>
<td>288.6</td>
</tr>
<tr>
<td>6. Outfit and Furnishings</td>
<td>478.3</td>
<td>32.2</td>
<td>280.1</td>
</tr>
<tr>
<td>7. Armament</td>
<td>153.9</td>
<td>36.1</td>
<td>240.2</td>
</tr>
<tr>
<td><strong>Building Margin</strong></td>
<td>83.7</td>
<td>49.0</td>
<td>245.7</td>
</tr>
<tr>
<td><strong>Total Light Ship</strong></td>
<td>5929.3</td>
<td>26.0</td>
<td>271.8</td>
</tr>
</tbody>
</table>

### Full Loads*

<table>
<thead>
<tr>
<th>Wt (Tons)</th>
<th>VCG</th>
<th>LCG **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew &amp; Effects</td>
<td>29.7</td>
<td>29.5</td>
</tr>
<tr>
<td>Ship Ammunition</td>
<td>78.4</td>
<td>24.7</td>
</tr>
<tr>
<td>Aircraft (Helo)</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Provisions &amp; Stores</td>
<td>34.6</td>
<td>27.0</td>
</tr>
<tr>
<td>General Stores</td>
<td>5.7</td>
<td>25.8</td>
</tr>
<tr>
<td>Aeronautical Stores</td>
<td>3.1</td>
<td>5.6</td>
</tr>
<tr>
<td>Potable Water</td>
<td>40.9</td>
<td>11.2</td>
</tr>
<tr>
<td>Lube Oil (Ship)</td>
<td>32.1</td>
<td>12.9</td>
</tr>
<tr>
<td>Lube Oil (Helos)</td>
<td>9.5</td>
<td>15.7</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>1588.4</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Total Loads</strong></td>
<td>1975.8</td>
<td>10.0</td>
</tr>
<tr>
<td>Ship - Full Load Cond. D</td>
<td>7890.1</td>
<td>22.0</td>
</tr>
</tbody>
</table>

### Propulsion Characteristics
- **Full Power:** 80,000 SHP
- **Cruising:** 14,067 SHP

### Machinery

<table>
<thead>
<tr>
<th>No./Ship</th>
<th>Rating</th>
<th>Manufacturer</th>
<th>Unit Weight Dry (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Turbine LM2500</td>
<td>4</td>
<td>20,500 bhp</td>
<td>General Electric</td>
</tr>
<tr>
<td>Reduction Gear</td>
<td>2</td>
<td>300,000 lb thrust (max.)</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>Propeller, CRP</td>
<td>2</td>
<td>220</td>
<td>Bird-Johnson</td>
</tr>
</tbody>
</table>

### Electric Plant
- **SS Gas Turbine Generators:** 3, 2,000 kw, Stewart & Stevenson, 23.9

### Auxiliary Plant
- **Distilling Plants:** 2, 6,000 gal/day, Aqua-Chem, 2.7
- **Air Conditioner Plant:** 0.3, 150 Tons, York, 7.7
- **Refrigeration Units:** 2, 1.5 ton, York, 0.8
- **Waste Heat Boilers:** 3, 7,000 lb/hr, Condenser Service & Eng'rs, 8.0
- **Air Compressors:** 2, 100 SCFM, Ingersoll Rand, 2.2
- **Anchors:** 2, 8,000 lb (Navy Stockless), 4.0
- **Rudders:** 2, 162 ft Spade, -----, 20.8

*(From Final Weight Report dated 8 October 1990)

**Referenced from Forward Perpendicular)

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*Note: Inch-pound units are shown in example, however SI units are applicable when specified.*

FIG. S3.11 Example of Design and Weight Data Sheet Format

22
S3.3.5.6 Weight Distribution Report—A longitudinal weight distribution shall be submitted in a tabulated format in accordance with the standard longitudinal station breakdown. Weight and longitudinal center of gravity shall be determined for each ship station for both light ship and full-load condition. The resultant total weight and longitudinal center of gravity for the weight distribution report shall equal the values reflected in the basic weight estimate or report for the same reporting period.

S3.3.5.7 Electronic Media—Electronic media shall be submitted that describes the applicable reports in the format specified in the Annex and in accordance with the requirements set forth in ANSI X3.4.

S3.3.5.8 Weight and Moment Trade-Off Studies—Trade-off studies comprise various engineering and technical studies directed toward determining detail weight data. These analytical studies are used to support design change proposals and support recommendations for reversing trends toward exceeding established margins or limits. These studies are conducted on an “as requested” basis and contain detailed weight calculations reflecting the impact of the study on ship displacement, KG, list, and trim. There is no fixed format for the weight calculations, but each submittal shall use the ESWBS classification system to structure and summarize the data.

S4. NOTES

S4.1 Issue of DODISS—When this guide is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see S1.1 and S1.2).

S4.2 Data Requirements—The following Data Item Descriptions (DIDs) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this guide is applied on a contract to obtain the data, except when DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

S4.3 Reports Interface—The interface of weight estimates and reports is depicted in Fig. S3.11.

S4.4 This guide satisfies a requirement to combine all weight control technical requirements for all phases of U.S. Navy surface ship acquisition contracts into a single document.

ANNEX

(Mandatory Information)

A1. INPUT DATA FILE FORMAT AND TRANSFER

A1. Scope

A1.1 Scope—This annex contains the required format for completing the standard Navy weight report input data files. This annex is a mandatory part of this guide. The information contained herein is intended for compliance (see S4.2).

A1.2 Format—Input data files, when required by the design contract or ship specifications, shall be in accordance with the format specified in Annex A1. In general, for each item in the weight estimate there shall be two lines of data in the file. The first line is mandatory and shall contain information regarding the weight and center of gravity of the item. The second line is optional, depending upon the specification requirements, and shall contain information regarding the inertia characteristics of the item. An example of the Navy standard weight estimate format is shown in Fig. A1.1.

A1.2.1 First Line of Data—The format for the first line of data is as follows:

A1.2.1.1 Columns 1 through 5, Classification Number—Columns 1 through 3 are based on the Expanded Ship Work Breakdown Structure (ESWBS) (see NAVSEA S9040-AA-IDX-010/SWBS 5D). Columns 4 and 5 provide for special subtotals within the classification number. Columns 4 and 5 shall contain only numeric data. Generally, two zeroes are used to designate an ESWBS element title. For example, Main Deck would be designated 13100 for ESWBS. Note that ESWBS subgroups ending in a zero are not to be used for input data, such as 110, 120, 230, 240, and so forth.

A1.2.1.2 Column 6—Column 6 is used for functional category designation when required for nuclear-powered ships. These categories are defined by NAVSEA 0900-LP-039-9020.

A1.2.1.3 Columns 7 through 10, Item Number—The item number provides the means of identification of each line within any five-digit element number. The following rules apply:

(a) Each line shall have an item number.

(b) All titles representing any of the basic ESWBS titles shall include a zero in Column 10.

NOTE: A1.1—Titles for special subtotals within an ESWBS element may contain any item number desired.
FIG. A1.1 Example of Navy Standard Weight Estimate Format
(c) Care shall be taken not to repeat any item numbers within a five-digit element.

(d) Do not use any leading zeroes in the item number, such as 0010.

(e) Item numbers for entries should be entered in increments of ten, such as 10, 20, and 30, instead of 1, 2, and 3.

(f) All item numbers shall be right justified.

A1.2.1.4 Column 11, Station—This column is used in conjunction with the standard longitudinal weight distribution for subsequent strength calculations. For weight distribution, the ship is divided into 22 stations which are lettered A through X (excluding I and O). Station A is designated to contain all items whose longitudinal center of gravity (LCG) is forward of the forward perpendicular. Station B contains all items with an LCG between the forward perpendicular and ship Station 1. Station C contains items between ship Station 1 and ship Station 2, and so on to Station X, which contains all items aft of the aft perpendicular. For each item (except titles and items with no weight), Column 11 shall contain a letter from A through X (excluding I and O), unless one of the following special options is used:

(a) An asterisk inserted in Column 11 for any item indicates the weight will be automatically distributed in a 22–station longitudinal distribution in proportion to the basic hull structure. The basic hull structure for ESWBS consists of Group 1 from 110 through 159, except 114 and 123 through 126. Items in the basic hull structure shall not use the asterisk option.

(b) A digit of 2 through 9 in Column 11 indicates the weight for the given item will be distributed over 2 through 9 stations centered about the item’s LCG. If enough stations are not available to do a particular distribution, the distribution will be done over as many stations as are available. For instance, if a six-station distribution is required within two stations of either end of the ship, then a four-station distribution will occur.

A1.2.1.5 Column 12, Special Designator—This column shall contain designators established by the government. Where no designator is applicable, this column shall be left blank. In the event of a conflict in determining which designator is to be used, the order of precedence shall be by alphabetical order. This designator provides for dual purpose as follows:

(a) Provides for extractions across the entire ship for summaries, such as plates, extruded shapes, weldments, primary, secondary, and others as required. (b) Provides for listing within the three-digit element, such as controls, components, distribution, and others as required.

(c) The following designators are applicable:

   C – Controls, such as valves, switches, regulators, gear boxes, and shutters.

   D – Distribution items, such as ducts, pipe, wire, wireways, connectors, waveguides, propeller shafts, and propeller shaft bearings.

   E – Plating and sheeting.

   F – Forgings, extruded shapes, rolled shapes, built-up shapes, and castings.

   G – Weldments.

   M – Major components, such as air conditioner units, antennas, actuators, batteries, blowers, boilers, compressors, computers, cranes, davits, distillers, transmitters, receivers, transceivers, engines, fans, generators, motors, propellers, pumps, turbines, winches, and replenishment-at-sea (RAS) equipment.

   P – Secondary, peripheral, and interface components, such as hydraulic reservoirs, electrical power supplies, nonintegral tanks, filters, heat exchangers (for system), and subbases.

A1.2.1.6 Column 13, Special Modifier—This column shall contain a modifier established by the government for the Column 12 designator for those items in Groups 1 through 7 only, that is, not including items of variable load. In the event a modifier cannot be determined, a Z shall be inserted. This modifier provides for dual purpose as follows:

(a) Provides for extractions across the entire ship for various material types, such as all steel, all aluminum, and others as required.

(b) Provides for special systems summaries across the entire ship or within certain elements, such as all payload, all habitability, and special systems such as hydrofoils and air cushions.

(c) The following modifiers are applicable:

   A – Aluminum.

   B – Brass and bronze.

   C – Copper, copper-nickel, and nickel-copper.

   D – Ordinary strength steel.

   E – Higher strength steel.

   F – Fiberglass, plastic, and insulation material.

   H – Habitability items, such as berthings, clothing and personal effects stowage, leisure systems, sanitary systems, messing, personal service, utility, and work systems. (This modifier shall supersede any material-type modifiers.)

   J – Wood material.

   K – Liquids.

   L – Lead.

   M – Miscellaneous metallic material.

   N – Miscellaneous nonmetallic material.

   P – Payload, which includes items that are peculiar to the specific missions of a particular ship, such as minesweep gear on a minesweeper, oceanographic gear on an oceanographic ship, and so forth. (This modifier shall supersede any material modifiers.)

   W – Welding, riveting, and fastening.

A1.2.1.7 Columns 14 through 45, Description—These 32 columns shall be used to describe each item adequately. Whatever is entered as input data is reproduced exactly on the weight estimate or report printout. Any combination of alphanumeric characters or blanks can be used. Clear and complete description is essential. However, if budget weights are being used, the description field shall be limited to 24 columns (Columns 14 through 37). Columns 38 through 45 will then be used for budget weights (see A1.2.1.8).

A1.2.1.8 Columns 38 through 45, Budget Weight—Budget weight, if used, is entered in pounds on ESWBS titles only. This allows weight values from 0 to 99 999 999 lbs (to be entered 999999999).

A1.2.1.9 Columns 46 through 53, Unit Weight—Always enter unit weight of any item in pounds. The broken line on the Standard Navy Transmittal Form (NA VSEA 5230/32) between Columns 51 and 52 provides a decimal point, allowing a unit weight up to 999 999.99 lbs. When the unit weight is a whole number, enter two zeroes behind the implied decimal point. If the weight is a deduction, enter a minus sign (–) immediately before the unit weight number.

A1.2.1.10 Columns 54 through 57, Number of Units—Values from 0.001 to 999 units can be entered. This number is multiplied by unit weight to produce total weight for each line item. Unit weight, number of units, and total weight are all printed in the detail output.

A1.2.1.11 Columns 58 through 62, Vertical Center of Gravity (VCG)—These columns shall be used for entering the VCG of each item. The VCGs shall be carried out to the hundredth
decimal place. When the VCG is a whole number, two zeroes must be entered after the decimal point. If the VCG is negative (a weight below the baseline), enter a minus sign immediately before the VCG number. All VCGs are measured in feet. The VCG will be multiplied by the computed total weight, and the resultant vertical moment will be printed.

A1.2.1.12 Columns 63 through 67, Longitudinal Center of Gravity (LCG)—These columns shall be used for entering the LCG of each item. The LCG is measured in feet and carried out to the hundredth decimal place. Always enter a positive LCG; no sign is necessary. When the LCG is a whole number, enter two zeroes behind the implied decimal point. The LCG will be multiplied by the computed total weight, and the resultant longitudinal moment will be printed.

A1.2.1.13 Column 68, LCG Sign—As previously mentioned, the LCG is always entered as a positive value. Enter “F” or “A” to indicate whether the weight is located forward or aft of the longitudinal reference datum. A blank in Column 68 is interpreted to mean “A” or aft.

A1.2.1.14 Columns 69 through 73, Transverse Center of Gravity (TCG)—These columns shall be used for entering the TCG of each item. The TCGs shall be carried out to the hundredth decimal place. When the TCG is a whole number, two zeroes must be entered after the decimal point. All TCGs are measured in feet port or starboard of the centerline, with the exception when port and starboard symmetry exists. If a line item has port and starboard symmetry, the TCG is measured in feet from the transverse center of one side (port or starboard) of the symmetrical item. This is essential to calculate the weight moment of inertia value of the line item. Always enter a positive TCG; no sign is necessary. If the TCG is not applicable, leave Columns 69 through 73 blank. The TCG will be multiplied by the total weight, and the resultant transverse moment will be printed.

A1.2.1.15 Column 74, TCG Sign—As mentioned previously, the TCG is always entered as a positive value. Enter “P” or “S” to indicate whether the weight is port or starboard of the centerline. However, when a line item has port and starboard symmetry about the centerline, enter “X” to indicate the transverse center of one side (port or starboard) of the symmetrical line item. This distance will only be used to calculate the weight moment of inertia value of the line item. A blank in Column 74 is interpreted to mean “P” or port.

A1.2.1.16 Column 75, Reservation Indicator (RES)—This column is used to indicate reservation items or design responsibility. The letter “R” shall be used to designate a reservation item. The letters “A” through “Z” (except “R”) may be used, as required, to indicate design responsibility, such as:

H – Hull design.
M – Machinery design.
E – Electrical design.

A1.2.1.17 Column 76, Reason for Change—This column is used to indicate the reason for change as follows:

0 – Nomenclature change (no weight change).
1 – Contract modification change.
2 – Government-furnished material change.
3 – Change to class status, such as estimated to calculated or calculated to actual.
4-9 and A-Z user-assigned reasons. The column appears under “CHG” in the output.

A1.2.1.18 Column 77, Material Source Indicator—The column is used to indicate the source of an item as follows:

G – Government-furnished material.
F – Contractor-fabricated material.
P – Contractor-purchased material.

A1.2.1.19 Column 78, Class Status—Used to indicate the confidence of the weight value entered for the line item as follows:

E – Estimated weight.
A – Actual scale weight.
V – Vendor or catalog weight (to be changed to “A” upon actual weight determination of the item).

A1.2.20 Columns 79 and 80, Report Number—Enter the report number in which the change was first incorporated. Report Number “AO” shall be used for the first submittal of input. Line items changed before the first periodic weight report shall carry Report Number “BO” for the first such change, “CO” for the second, and so forth. The first periodic weight report shall have Column 79 blank, and a “1” in Column 80, and so forth. Deletions may contain the letters “DD” in Columns 79 and 80, instead of a report number, or the deletion line may be erased.

A1.2.2 Second Line of Data—The second line of data for each item contains the gyradius data for the item and immediately must follow the first line of data in the file. The format for the second line of gyradius data is as follows:

A1.2.2.1 Columns 1 through 5, Classification Number—These columns must contain the same five-digit classification number as the line of weight data that precedes it in the file.

A1.2.2.2 Column 6, I_o Designator—An asterisk (*) must be included in this field to designate the line as a second line containing inertia data for the previous line.

A1.2.2.3 Columns 7 through 10, Item Number—These columns must contain the same item number as the preceding line that contains the weight data for the item.

A1.2.2.4 Column 20, Shape of I_o Item—This field is used to indicate what kind of shape is to be used to estimate the I_o for the weight item. The following are shapes that may be used:

0 – The I_o calculation is to be the ratio or a percentage of a three-digit element's I_o.
1 – The I_o data are actual inertias.
2 – Rectangular prism.
3 – Hollow frustum of a cone.
4 – Hollow right circular cylinder.
5 – Hollow right rectangular cylinder.
6 – Hollow hemisphere.
7 – Square diamond.

Drawings showing the geometry and orientation of Shapes 2 through 7 can be found in Fig. A1.2. If this field is blank or contains a zero, the I_o will be calculated as a percentage of the three-digit element specified in Columns 41 through 50.

A1.2.2.5 Column 25, Orientation of the I_o Shape—This field is used to define the relationship between the local
coordinate system of the \( I_0 \) item as shown in Fig. A1.2 and the ship’s coordinate system. The entries to be used are as follows:

0 – \( X \) axis of the shape as shown in Fig. A1.2 is oriented in the ship’s longitudinal direction.

1 – \( X \) axis of the shape as shown in Fig. A1.2 is oriented in the ship’s transverse direction.

2 – \( X \) axis of the shape as shown in Fig. A1.2 is oriented in the ship’s vertical direction.

**NOTE A1.2**—The orientation of the shape relative to the ship’s coordinate system need not have any sign for the calculation of the inertia. For example, the inertia of the pyramid (Shape 5 in Fig. A1.2) about all three axes is the same whether the point of the pyramid is pointing in the positive \( X \) (to the right) or negative \( X \) direction (to the left). Therefore, for an item that is to be modeled as a pyramid with the point oriented to the stern of the ship, the value to be entered for the orientation in Column 25 would still be “O,” which is the same as if it were pointing to the bow.
A1.2.2.6 *Columns 31–40, X-Dimension*—For each of the shape definitions given in Column 20, the following information must be entered. The format for this field is right justified with an implied decimal point between Columns 38 and 39.

<table>
<thead>
<tr>
<th>Shape (Column 20)</th>
<th>X-dimension (Columns 31–40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or Blank</td>
<td>Blank or zero means the ratio of current weight to the weight of the specified element (entered in the Y-dimension field) is used to calculate the ( I_x ) or ( I_y ) (if 999 is entered in the Z-dimension field) or both, based on the specified element’s ( I_x ) or ( I_y ) or both. Percentage, which is used to calculate the item’s ( I_x ) or ( I_y ) or both, based on the specified element’s (entered in the Y-dimension field) ( I_x ) or ( I_y ) or both. For 1% enter 100, for 0.05% enter 5, and so forth.</td>
</tr>
<tr>
<td>1</td>
<td>( l_x ) about the local axis oriented in the ship’s longitudinal direction.</td>
</tr>
<tr>
<td>2, 3, 4, 5, 7</td>
<td>X-dimension (A of Fig. A1.2); Blank.</td>
</tr>
<tr>
<td>6</td>
<td>Blank.</td>
</tr>
</tbody>
</table>

A1.2.2.7 For the percentage option (0 or blank in Column 20), there are two possible options for calculating the \( I_x \) or \( I_y \) terms or both. For the first option, the X-dimension field is left blank, and there is a three-digit element number contained in the Y-dimension field. For this case, the \( I_x \) or \( I_y \) for the data line will be calculated as a percentage of the \( I_x \) or \( I_y \) for the specified element. The percentage used will be the weight of the data line to the element weight. If 999 is entered in the Z-dimension field, the \( I_x \) or \( I_y \) will be calculated in a similar manner. If a percentage is inserted in the X-dimension field and a three-digit element number is in the Y-dimension field, the \( I_x \) or \( I_y \) will be calculated as the defined percentage of the \( I_x \) or \( I_y \) for the specified element. If 999 is entered in the Z-dimension field, the \( I_x \) or \( I_y \) will be calculated in a similar manner.

A1.2.2.8 *Columns 41–50, Y-Dimension*—For each of the shape definitions given in Column 20, the following information must be entered. The format for this field is right justified with an implied decimal point between Columns 48 and 49.

<table>
<thead>
<tr>
<th>Shape (Column 20)</th>
<th>Y-dimension (Columns 41–50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or Blank</td>
<td>Three-digit element on which ( I_x ) or ( I_y ) or both percentage calculation is based. If blank, the calculation will be based on the current three-digit element.</td>
</tr>
<tr>
<td>1</td>
<td>( I_x ) about local axis oriented in the ship’s transverse direction.</td>
</tr>
<tr>
<td>2, 3, 4, 5, 7</td>
<td>Y-dimension (B of Fig. A1.2); Outer Radius (R of Fig. A1.2)</td>
</tr>
<tr>
<td>6</td>
<td>Blank.</td>
</tr>
</tbody>
</table>

A1.2.2.9 *Columns 51–60, Z-Dimension*—For each of the shape definitions given in Column 20, the following information must be entered. The format for this field is right justified with an implied decimal point between Columns 58 and 59.

<table>
<thead>
<tr>
<th>Shape (Column 20)</th>
<th>Z-dimension (Columns 51–60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or Blank</td>
<td>If blank, only the ( I_x ) calculation will be done using a ratio or an entered percentage. If 999 is entered, then both the ( I_x ) and ( I_y ) calculation will be done using a ratio or an entered percentage.</td>
</tr>
<tr>
<td>1</td>
<td>( I_x ) about the local axis oriented in the ship’s vertical direction.</td>
</tr>
<tr>
<td>2, 3</td>
<td>Z-dimension (C of Fig. A1.2); Inner Radius (r of Fig. A1.2)</td>
</tr>
<tr>
<td>6, 7</td>
<td>Blank.</td>
</tr>
</tbody>
</table>

A1.2.2.10 *Columns 61–70, T-Dimension*—For each of the shape definitions given in Column 20, the following information must be entered. The format for this field is right justified with an implied decimal point between Columns 68 and 69.

<table>
<thead>
<tr>
<th>Shape (Column 20)</th>
<th>T-dimension (Columns 61–70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, 1, 2, 4, 5, 7</td>
<td>Blank.</td>
</tr>
<tr>
<td>3, 6</td>
<td>Thickness (t of Fig. A1.2).</td>
</tr>
</tbody>
</table>

A1.2.2.11 *Columns 79–80, Report Number*—Enter the report number in which the change was first incorporated as described for the first line of data.

A1.3 *General Input Data Requirements:*

A1.3.1 *Load Titles*—Line items for titles shall be prepared for each required load condition, and for each load element comprising that condition, in accordance with ESWBS in the following format:

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Alpha load condition designator.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns 2 and 3</td>
<td>Load element number.</td>
</tr>
<tr>
<td>Columns 4 and 5</td>
<td>Zeroes.</td>
</tr>
<tr>
<td>Column 10</td>
<td>Zero.</td>
</tr>
<tr>
<td>Columns 14 through 37</td>
<td>Load element title.</td>
</tr>
</tbody>
</table>

A1.3.2 *Load Details*—Loads for ESWBS are classified in much the same manner as light ship elements in Groups 1 through 7 and follow the same format. Input data must be prepared for all detail load items comprising the full-load condition (F in Column 1). The letters “A” through “L” are used in Column 1 to indicate various other loading conditions.

A1.3.3 *Margins*—Margins for ESWBS are classified in accordance with ESWBS. The weight and moment of each margin will be distributed automatically over the 22 longitudinal stations in proportion to the light ship weight distribution. The margins either can be input as a total weight or as a percentage of total light ship displacement. Line items for margins are prepared in a similar manner to light ship details. The first line item of the margin group shall be a title of the form “M0000—0—Margins,” beginning in Column 1. Margin depletions are handled as negative detail weight entries, in the same manner as light ship details, and follow the same format. Margin options are as follows:

A1.3.3.1 *Option 1, Input Weight*—Enter the total margin weight in pounds in Columns 46 through 53 and centers of gravity as desired. All or any centers of gravity may be left blank. The margins will then be automatically positioned at the light ship centers of gravity.

A1.3.3.2 *Option 2, Percentage*—Margin may be computed as a percentage of total light ship. In the unit weight, Columns 46 through 53, enter the percentage desired (for example: 4% = 4.00). Enter zero in Column 57 of number of units. Centers of gravity may be entered or left blank. If left blank, margins will be placed at light ship centers of gravity.

A1.3.4 *Titles*—Titles for Groups 1 through 7 are included in the Navy program. All other titles shall be prepared by the user. A title shall be prepared for each of the ESWBS elements.

A1.4 *Data Transfer*—Input data files, when required by the contract or ship specifications, shall be transferred on electronic media and in ASCII format.
X1. SUGGESTED FORMS FOR WEIGHT ESTIMATION

X1.1 The suggested forms for weight estimation are shown in Figs. X1.1-X1.8.
### Stability and Trim Calculation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Item</th>
<th>Displ. and Weight</th>
<th>Cg Above Base</th>
<th>Cg From</th>
<th>Free Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull Structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outfit</td>
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<tr>
<td>Machinery</td>
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<tr>
<td><strong>Subtotal</strong></td>
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<td>Fixed Ballast</td>
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</tr>
<tr>
<td><strong>Subtotal</strong></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Weight Margin</td>
<td>%</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Kg Margin</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Total - Ship in Condition</strong></td>
<td>Light Ship</td>
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</tr>
</tbody>
</table>

**Mean S.W. Draft**

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<th>Mean S.W. Draft</th>
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<tbody>
<tr>
<td>LCG</td>
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<tr>
<td>LCF</td>
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**Km**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>LCB</td>
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<tr>
<td>DRAFT FWD,</td>
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</tbody>
</table>

**Kg**

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<tr>
<th>Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIM LEVER FWD, AFT</td>
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<tr>
<td>DRAFT AFT</td>
</tr>
</tbody>
</table>

**Gm**

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>MOMENT TO TRIM</td>
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<tr>
<td>DRAFT AFT</td>
</tr>
</tbody>
</table>

**Corr. Fcr. F.S.**

<table>
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<tr>
<th>Corr. Fcr. F.S.</th>
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</thead>
<tbody>
<tr>
<td>TRIM IN FWD, AFT</td>
</tr>
</tbody>
</table>

**Gm Available**

<table>
<thead>
<tr>
<th>Gm Available</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Gm Required</th>
</tr>
</thead>
</table>

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**Fig. X1.1 Sample Form #1**
<table>
<thead>
<tr>
<th>CODE</th>
<th>ITEM</th>
<th>WEIGHT</th>
<th>VERT. LEV.</th>
<th>VERT. MOM.</th>
<th>LONG. LEV.</th>
<th>LONG. MOM.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0</td>
<td>Stem casting</td>
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</tr>
<tr>
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<td>Stern frame casting</td>
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</tr>
<tr>
<td>2</td>
<td>Boss casting</td>
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<tr>
<td>3</td>
<td>Shaft struts</td>
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<tr>
<td>4</td>
<td>Misc. Hull Castings</td>
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<td>1-0</td>
<td>Forgings and Castings</td>
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</tr>
<tr>
<td>1</td>
<td>Flat Plate keel</td>
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</tr>
<tr>
<td>2</td>
<td>Shell plating</td>
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<tr>
<td>3</td>
<td>Bulwarks</td>
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<tr>
<td>4</td>
<td>Bilge keels</td>
<td></td>
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<tr>
<td>5</td>
<td>Boss plating</td>
<td></td>
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<tr>
<td>6</td>
<td>Rubbing strips and fenders</td>
<td></td>
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<tr>
<td>7</td>
<td>Sea Chests / Skin coolers</td>
<td></td>
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<tr>
<td>8</td>
<td>Skegs</td>
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<tr>
<td>9</td>
<td>Thruster Tunnels / Wells</td>
<td></td>
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</tr>
<tr>
<td>2-0</td>
<td>Shell Plating</td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Center vertical keel</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>Trans. framing in 1.B.</td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>Long. framing in 1.B.</td>
<td></td>
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<tr>
<td>4</td>
<td>Trans. framing outside 1.B.</td>
<td></td>
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<tr>
<td>5</td>
<td>Framing in peaks</td>
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<tr>
<td>6</td>
<td>Tansom and cants</td>
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</tr>
<tr>
<td>7</td>
<td>Web frames</td>
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</tr>
<tr>
<td>8</td>
<td>Long'l Girdle Ring</td>
<td></td>
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<tr>
<td>9</td>
<td>Long'l Stringer Ring</td>
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<td>3-0</td>
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<tr>
<td>4-0</td>
<td>Deck Plating and Beams</td>
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<tr>
<td>1</td>
<td>Main trans. W.T. bhds.</td>
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</tr>
<tr>
<td>2</td>
<td>Trans. W.T. and O.T. bhds</td>
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<tr>
<td>3</td>
<td>Long. W.T. and O.T. bhds</td>
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<tr>
<td>4</td>
<td>Structural N.W.T. bhds</td>
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<tr>
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<td>Non-structural bhds</td>
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<tr>
<td>6</td>
<td>Trunks - structural</td>
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<td>Trunks - non-structural</td>
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<tr>
<td>8</td>
<td>Stair enclosures</td>
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</tr>
<tr>
<td>9</td>
<td>Hatch Coamings</td>
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</tr>
<tr>
<td></td>
<td>Drill Wells / Leg Wells</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Bulkheads and Trunks</td>
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</tr>
</tbody>
</table>

FIG. X1.2 Sample Form #2
<table>
<thead>
<tr>
<th>CODE</th>
<th>ITEM</th>
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**Superstructures**

**SUB TOTAL GROUPS 0 THROUGH 8**

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| 1    | Welding                    |        |            |            |            |            |
| 2    | Mill Tolerance             |        |            |            |            |            |
| 3    |                             |        |            |            |            |            |
| 4    |                             |        |            |            |            |            |
| 5    |                             |        |            |            |            |            |
| 6    |                             |        |            |            |            |            |
| 7    |                             |        |            |            |            |            |

**Riveting and Welding**

**TOTAL HULL STRUCTURE**

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FIG. X1.5 Sample Form #5
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FIG. X1.6 Sample Form #6
## MACHINERY SUMMARY
(Weight Calculations)

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**FIG. X1.7 Sample Form #7**
Standard Guide for
Cable Splicing Installations

This standard is issued under the fixed designation F 1835; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides direction and recommends cable splicing materials and methods that would satisfy the requirements of extensive cable splicing in modular ship construction and offers sufficient information and data to assist the shipbuilder in evaluating this option of cable splicing for future ship construction.

1.2 This guide deals with cable splicing at a generic level and details a method that will satisfy the vast majority of cable splicing applications.

1.3 This guide covers acceptable methods of cable splicing used in shipboard cable systems and provides information on current applicable technologies and additional information that the shipbuilder may use in decision making for the cost effectiveness of splicing in electrical cable installations.

1.4 This guide is limited to applications of 2000 V or less, but most of the materials and methods discussed are adaptable to higher voltages, such as 5-kV systems. The cables of this guide relate to all marine cables, domestic and foreign, commercial or U.S. Navy.

1.5 The values stated in SI units shall be regarded as standard. The values given in parentheses are inch-pound units and are for information only.

1.6 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the application of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
B 8 Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
D 2671 Test Methods for Heat-Shrinkable Tubing for Electrical Use

2.2 IEEE Standards:
IEEE 45 Recommended Practice for Electrical Installations on Shipboard
2.3 UL Standards:
UL STD 224 Extruded Insulating Tubing
UL STD 486A Wire Connectors and Soldering Lugs for Use with Copper Conductors
2.4 IEC Standards:
IEC 228 Conductors of Insulated Cables
2.5 Federal Regulations:
Title 46 Code of Federal Regulations (CFR), Shipping
2.6 Military Specifications:
MIL-T-16366 Terminals, Electric Lug and Conductor Splices, Crimp-Style
MIL-T-7928 Terminals, Lug, Splices, Conductors, Crimp-Style, Copper

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 adhesive, n—a wide range of materials used extensively for bonding and sealing; coating added to the inner wall of heat-shrinkable tubing to seal the enclosed area against moisture. Adhesive is for pressure retention and load-bearing applications (see also sealant).

3.1.2 barrel, n—the portion of a terminal that is crimped; designed to receive the conductor, it is called the wire barrel.

3.1.3 butt connector, n—a connector in which two conductors come together, end to end, but do not overlap and with their axes in line.

3.1.4 butt splice, n—device for joining conductors by butting them end to end.

3.1.5 circumferential crimp, n—final configuration of a barrel made when crimping dies completely surround the barrel and form symmetrical indentations.

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1 This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.


2 Annual Book of ASTM Standards, Vol 02.03.

4 Available from the Institute of Electrical and Electronic Engineers, IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08854-1331.

5 Available from Underwriters Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

6 Available from the International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH-1211, Geneva 20, Switzerland.

7 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5098, Attn: NPODS.
3.1.6 compression connector, n—connector crimped by an externally applied force; the conductor is also crimped by such force inside the tube-like connector body.
3.1.7 cold-shrink tubing, n—tubular rubber sleeves that are factory expanded and assembled onto a removable core. No heat is used in installation. Also known as prestretched tubing (PST).
3.1.8 crimp connectors, n—tubular copper connectors made to match various wire sizes and fastened to the conductor ends by means of a crimping tool.
3.1.9 crimping die, n—portion of the crimping tool that shapes the crimp.
3.1.10 crimping tool, n—a mechanical device, which is used to fasten electrical connectors to cable conductors by forcefully compressing the connector onto the conductor. This tool may have interchangeable dies or “jaws” to fit various size connectors.
3.1.11 heat-shrink tubing, n—electrical insulation tubing of a polyolefin material, which shrinks in diameter from an expanded size to a predetermined size by the application of heat. It is available in various diameter sizes.
3.1.12 primary insulation, n—the layer of material that is designed to do the electrical insulating, usually the first layer of material applied over the conductor.
3.1.13 sealant, n—inner-wall coating optional to shrinkable tubing to prevent ingress of moisture to the enclosed area (see also adhesive).
3.1.14 splice, n—a joint connecting conductors with good mechanical strength and good conductivity.
3.1.15 tensile, n—amount of axial load required to break or pull wire from the crimped barrel of a terminal or splice.

4. Significance and Use

4.1 Splicing of cables in the shipbuilding industry, both in Navy and commercial undertakings, has been concentrated in repair, conversion, or overhaul programs. However, many commercial industries, including aerospace and nuclear power, have standards defining cable splicing methods and materials that establish the quality of the splice to prevent loss of power or signal, ensure circuit continuity, and avoid potential catastrophic failures. This guide presents cable splicing techniques and hardware for application to commercial and Navy shipbuilding to support the concept of modular ship construction.

4.2 This guide resulted from a study that evaluated the various methods of cable splicing, current technologies, prior studies and recommendations, performance testing, and the expertise of manufacturers and shipbuilders in actual cable splicing techniques and procedures.

4.3 The use of this guide by a shipbuilder will establish cable splicing systems that are: simple and safe to install; waterproof, corrosion, and impact resistant; industry accepted with multiple suppliers available; low-cost methods; and suitable for marine, Navy, and IEC cables.

5. General Requirements for Cable Splicing

5.1 Cable splicing requires that cable joints be insulated and sealed with an insulation equal in electrical and mechanical properties to the original cable. Cable splicing shall consist of a conductor connector, replacement of conductor insulation, replacement of the overall cable jacket, and where applicable, reestablishment of shielding in shielded cables and electric continuity in the armor of armored cables.

5.2 Nonsplice Applications—The only unacceptable area for a cable splice is established by regulations and concerns the restriction of being unable to splice cables in defined hazardous areas. Hazardous areas are locations in which fire or explosion hazards may exist as a result of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

6. Cable Splicing

6.1 Cable splicing presented in this guide uses a system of compression-crimp, tubular-metal connectors for butt connection of cable conductors and insulating systems of shrinkable tubing to reinsulate the individual conductors and replace the overall cable jacket.

6.2 Crimp Connectors—For splice connection of conductors, compression-crimped connectors shall be used for joining an electrical conductor (wire) to another conductor. The joint requires proper compression to achieve good electrical performance while not overcompressing and mechanically damaging the conductor. Compression connections are accomplished by applying a controlled force on a barrel sleeve to the conductor with special tools and precision dies.

6.3 Conductor Reinsulation—Thin-wall shrinkable tubing shall be used to reinsulate the conductor and the installed connector. The insulation tubing, when shrunk or recovered, shall be equal in electrical and mechanical properties to the original conductor insulation. Tubing used for conductor reinsulation does not require an interior adhesive sealant coating.

6.4 Cable Jacket Reinsulation—Shrinkable tubing shall be used to envelop the overall splice. To satisfy more abusive conditions that cable jackets are exposed to, a flame-retardant, thick-wall tubing construction with factory applied sealant shall be used.

7. Cable Preparation

7.1 Cables to be spliced shall be prepared to the dimensions specified in Fig. 1 and Fig. 2. Fig. 1 provides cable preparation for power cables from single to four conductor sizes. Dimensions for multiple conductor cables (conductor size of No. 14 or less) are shown in Fig. 2.

7.2 Care must be exercised when preparing the cable ends so that conductor insulation is not cut when removing the overall cable jacket, shield, or cable armor, where applicable. Similar care is required when removing the individual shield or insulation protecting the conductor to prevent cuts or nicks on the individual conductor strands.

7.2.1 Insulation cutting tools that limit depth of cut should be used to prepare cable ends so that underlying insulation is not cut. Similar care is required when removing the individual conductor insulation to protect the conductor copper strands from nicks and cuts.

7.2.2 Cable preparation shall result in stripping the individual conductors so that the bare copper is long enough to reach the full depth of the butt connector plus 3.2 mm (⅛ in.).

2
### FIG. 1 Splice Dimensions for Power Cables

**CONDUCTOR SIZE** | **A** | **B** | **C** | **D** | **E** | **F** | **G** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(AWG or MCM)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 to 10</td>
<td>203</td>
<td>127</td>
<td>50</td>
<td>76</td>
<td>102</td>
<td>178</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>(8)</td>
<td>(5)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(7)</td>
<td>(13)</td>
</tr>
<tr>
<td>9 to 4</td>
<td>279</td>
<td>178</td>
<td>76</td>
<td>76</td>
<td>152</td>
<td>254</td>
<td>356</td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td>(7)</td>
<td>(3)</td>
<td>(3)</td>
<td>(6)</td>
<td>(10)</td>
<td>(14)</td>
</tr>
<tr>
<td>3 to 1/0</td>
<td>330</td>
<td>203</td>
<td>76</td>
<td>102</td>
<td>152</td>
<td>279</td>
<td>406</td>
</tr>
<tr>
<td></td>
<td>(13)</td>
<td>(8)</td>
<td>(3)</td>
<td>(4)</td>
<td>(6)</td>
<td>(11)</td>
<td>(16)</td>
</tr>
<tr>
<td>2/0 to 250</td>
<td>381</td>
<td>254</td>
<td>127</td>
<td>102</td>
<td>254</td>
<td>381</td>
<td>635</td>
</tr>
<tr>
<td></td>
<td>(15)</td>
<td>(10)</td>
<td>(5)</td>
<td>(4)</td>
<td>(10)</td>
<td>(11)</td>
<td>(20)</td>
</tr>
<tr>
<td>300 to 500</td>
<td>495</td>
<td>330</td>
<td>165</td>
<td>102</td>
<td>330</td>
<td>495</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>19.5</td>
<td>(13)</td>
<td>(6.5)</td>
<td>(4)</td>
<td>(13)</td>
<td>(19.5)</td>
<td>(26)</td>
</tr>
<tr>
<td>650 to 2000</td>
<td>254</td>
<td>102</td>
<td>508</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>711</td>
</tr>
<tr>
<td></td>
<td>(10)</td>
<td>(4)</td>
<td>(20)</td>
<td>(28)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- All dimensions are in millimeters (inches are shown in parenthesis).
- Dimension "A" equals half the connector length plus 3 mm (1/8-inch). Bare copper on each conductor equals "A."

*FIG. 1 Splice Dimensions for Power Cables*
7.3 Match the geometrical arrangement between cables to be spliced using conductor color code identification to eliminate crossovers or mismatch when splicing.

7.4 Cable ends shall be in or near their final position before being spliced.

8. Materials and Tools

8.1 Cable Splicing Materials—The following sections provide an overview of the various splice materials. In addition, specific recommendations and suggested guidelines are offered that would enhance the cable splicing process.

8.1.1 Crimp-Type Connectors—Splice connectors shall be compression-type, butt connectors conforming to the requirements of UL STD 486A and shall be satisfactory to Section 20.11 of IEEE 45.

8.1.1.1 Connector shall be seamless, tin-plated copper.

8.1.1.2 Butt connector shall have positive center wire stops for proper depth of conductor insertion.

8.1.1.3 Connectors shall be marked with wire size for easy identification.

8.1.1.4 Connector shall have inspection holes to allow visual inspection for proper wire insertion.
8.1.1.5 Butt connector for wire sizes No. 10 (AWG) or larger shall be the “long barrel” type to permit multiple crimps on each side of the connector for greater tensile strength. The conductor ends shall be fully inserted to the “stop” at the center of the connector. For smaller conductor sizes (No. 10 AWG or less), a single crimp should be spaced half way between the end of the connector and the center wire stop.

8.1.1.6 Connector shall be color-coded in accordance with Table 1 or Table 2.

8.1.2 Conductor Reinsulating Material—To reinsulate the conductor and the installed connector, heat-shrink tubing shall be used. (see Table 3).

8.1.2.1 When recovered or shrink, the tubing used shall be equal to or greater than the thickness of the original conductor insulation.

8.1.2.2 Shrink tubing used for conductor reinsulation shall be heat-shrink tubing. The tubing shall be thin-wall cross-linked polyolefin tubing, flame-retardant (FR-1) construction in accordance with UL STD 224 requirements. Performance requirements shall include:

- Shrink ratio: 2:1
- Operating temperature range: –55 to +135°C
- Minimum shrinkage temperature: +121°C
- Longitudinal shrinkage: ≤5%
- Electrical rating: 600-V continuous operation
- Dielectric strength in accordance with Test Methods D 2671: 7.9 kV/mm (200 V/mil) min

8.1.2.3 Shrink tubing to cover the connection of individual conductors does not require an interior coating of adhesive (mastic) sealant.

8.1.3 Cable Jacket Replacement Materials—Several methods and a variety of materials are available that will provide the mechanical protection, moisture-sealing properties, and electrical performance characteristics needed in a cable splice. For a splice reliability and ease of installation replacement of cable jacket and to envelop the splice area, however, either the heat-shrink or the cold-shrink (prespun) type shall be used.

8.1.3.1 The tubing used, when recovered or shrunk, shall be equal to or greater than the thickness of the original conductor insulation (see Table 3).

8.1.3.2 The tubing used for cable jacket replacement shall be thick wall, also referred to as heavy-duty shrink tubing used for rejacketing of cables.

8.1.3.3 Shrink tubing shall be flame retardant (FR-1) in accordance with UL STD 224 requirements.

8.1.3.4 Tubing used for rejacketing of a splice bundle shall have an interior coating of adhesive (mastic) sealant.

8.1.3.5 Table 3 provides dimensions for thick-wall tubing used for rejacketing of cables.

8.1.3.6 Tubing shall have the following performance requirements:

- Shrink ratio: 3:1
- Operating temperature range: –55 to +135°C
- Minimum shrinkage temperature (for heat-shrink tubing): +121°C
- Longitudinal shrinkage: ≤5%
- Electrical rating: 600-V continuous operation
- Dielectric strength in accordance with Test Methods D 2671: 7.9 kV/mm (200 V/mil) min

8.1.4 Shield Terminations—Cables that require continued shielding shall have at least a 13-mm (1/2-in.) overlap between the replacement shielding material and the permanent shielding and shall be attached with either solder-type connectors or a mechanical connection using inner and outer compression (crimp-type) rings.

8.2 Splicing Tools:

8.2.1 Cable Preparation—The basic tools required for cable splice preparation include a cable cutter, measuring tape or ruler, and a wire insulation stripper. Following the cable preparation, the types of tools required to complete a cable splice include:

### TABLE 1 Connector Data (English Units)

<table>
<thead>
<tr>
<th>Conductor Size AWG or MCM Designation</th>
<th>Connector Overall Length (min)</th>
<th>Depth of Each Side of Barrel (min)</th>
<th>Overall Diameter of Barrel (Approximate)</th>
<th>Color Code</th>
<th>Conductor Nominal Diameter, in.</th>
<th>Number of Crimps/End</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>%</td>
<td>¼</td>
<td>0.150</td>
<td>–</td>
<td>0.025</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>%</td>
<td>¼</td>
<td>0.150</td>
<td>–</td>
<td>0.039</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>%</td>
<td>¼</td>
<td>0.150</td>
<td>–</td>
<td>0.049</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>%</td>
<td>¼</td>
<td>0.150</td>
<td>–</td>
<td>0.061</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>%</td>
<td>¼</td>
<td>0.150</td>
<td>–</td>
<td>0.077</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>%</td>
<td>½</td>
<td>0.212</td>
<td>–</td>
<td>0.092</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>%</td>
<td>½</td>
<td>0.212</td>
<td>–</td>
<td>0.108</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>1/4</td>
<td>½</td>
<td>½</td>
<td>red</td>
<td>0.146</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2/6</td>
<td>1/2</td>
<td>¼</td>
<td>blue</td>
<td>0.184</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>3/6</td>
<td>1/3</td>
<td>¾</td>
<td>gray</td>
<td>0.226</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2/3</td>
<td>1/3</td>
<td>¾</td>
<td>white</td>
<td>0.254</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2/5</td>
<td>1/3</td>
<td>¾</td>
<td>brown</td>
<td>0.282</td>
<td>2</td>
</tr>
<tr>
<td>1/2</td>
<td>2/6</td>
<td>1/4</td>
<td>½</td>
<td>green</td>
<td>0.317</td>
<td>4</td>
</tr>
<tr>
<td>½</td>
<td>2/8</td>
<td>1/4</td>
<td>½</td>
<td>pink</td>
<td>0.363</td>
<td>4</td>
</tr>
<tr>
<td>¾</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>black</td>
<td>0.407</td>
<td>4</td>
</tr>
<tr>
<td>2/3</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>orange</td>
<td>0.457</td>
<td>4</td>
</tr>
<tr>
<td>1/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>purple</td>
<td>0.514</td>
<td>4</td>
</tr>
<tr>
<td>2/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>yellow</td>
<td>0.577</td>
<td>4</td>
</tr>
<tr>
<td>3/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>white</td>
<td>0.628</td>
<td>4</td>
</tr>
<tr>
<td>4/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>red</td>
<td>0.682</td>
<td>4</td>
</tr>
<tr>
<td>5/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>brown</td>
<td>0.742</td>
<td>4</td>
</tr>
<tr>
<td>6/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>green</td>
<td>0.893</td>
<td>4</td>
</tr>
<tr>
<td>7/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>black</td>
<td>0.996</td>
<td>4</td>
</tr>
<tr>
<td>1/0</td>
<td>3/6</td>
<td>1/4</td>
<td>½</td>
<td>white</td>
<td>1.180</td>
<td>4</td>
</tr>
</tbody>
</table>

a Recommended colors for connectors; however, variations do exist between manufacturers.

b For conductors No. 1 or larger, the type of crimping tool used determines the number of crimps to be made. Number and location of compression points (crimps) shall be in accordance with the manufacturer’s recommendations.
splice include the crimp tool for compression of the butt connectors and a heat source for reducing heat-shrinkable tubing.

8.2.2 Crimping Tools—The crimp compression method for making electrical cable splices as recommended in this guide consists of compressing a butt connector onto the wire very tightly so that good metal-to-metal contact is achieved. A crimping tool is necessary so that the process is controlled, the crimp is made easily and correctly and can be reproduced reliably.

8.2.2.1 This guide recommends the use of compression systems that coordinate connectors, crimping tools and dies, and include built-in installation and inspection features that prevent improper field connections.

8.2.2.2 The crimping tool shall be a single-cycle type, requiring full-cycle compression before release. Full-cycle control requires that the crimping tool to be closed to its fullest extent, thereby completing the crimping cycle before the tool can be opened.

8.2.2.3 Mechanical-type (manual) compression tools used for crimping connectors shall be a one-cycle device and require full compression before release.

8.2.2.4 Hydraulic crimping devices shall have an emergency release mechanism to abort the crimp cycle if necessary.

8.2.2.5 Crimp tool shall allow easy visual field check for proper tool adjustment with butting surfaces.

8.2.2.6 Crimping tool and crimp dies shall result in circumferential-shaped configuration.

8.2.3 Heat Guns—Heat-shrink tubing installation requires that the source of heat be controllable. Limited electric heat guns and hot air blowers that are portable and provide even controlled heat at nozzle temperatures of 260 to 399°C (500 to 750°F) are recommended devices for installing heat-shrink tubing. Propane torches shall be used with extreme care. Torches shall not be used to shrink thin-wall tubing.

9. Quality Assurance

9.1 General Guidelines for Quality Assurance—For extensive cable splicing activities, such as found with modular ship construction techniques, it is recommended that a material control program and a personnel training program that includes certification of personnel for both splicing installation and inspection. Quality control issues are of major significance and factors that can be controlled and monitored by the shipbuilder before, during, and following cable splicing. A cable splicing program as envisioned for modular ship construction should include use of only approved materials and devices, only qualified personnel to make the electrical cable splices, and establish inspection procedures, using only qualified inspectors, to verify proper installation.

9.2 Material Control—Since crimping is a mechanical process and, by controlling the material and dimensional properties of the conductor, the butt connector, and the crimp tool, the reliability of the crimped connection may be controlled closely. An in-process quality assurance program based on controlled distribution of materials and tools should be established. For installation tools, the program should include inspections to assure that:

9.2.1 Splicing equipment shall be inspected before the first use each month to verify the performance of insulation removal devices and of crimping tools.

9.2.2 Crimp tool dies shall be checked before the first use each month for correct tolerances.

9.3 Material Procurement; Recommended Use of Kits—A material control program should adopt the use of cable splice kits. Splice kits may be procured directly from a number of manufacturers.
qualified manufacturers or can be assembled by the shipbuilder from quantity-purchased materials for the various types and sizes of materials necessary. All kits shall be for one-to-one cable splices. For selection of cable-splice kit, the following minimum information should be established:

9.3.1 Number of conductors in the cable,
9.3.2 Size (gage) of each conductor,
9.3.3 Ground wire size, if included,
9.3.4 Shielded or nonshielded; individual, overall
9.3.5 Only one splice per kit is recommended, with basic materials of the kit to include butt connectors, conductor reinsulation material, cable jacket replacement material, and shield braid sleeve connectors, when required.

10. Installation

10.1 Installation Guidelines—Various factors and conditions are significant in contributing to a successful splice. These items are summarized in this section as installation guidelines for the use of shipbuilders and others. These basic factors should be emphasized in any quality assurance or training programs established in support of a major cable splicing program.

10.2 Splice Locations—There are no significant differences in installing vertical splicing and horizontal splicing, however after splicing is completed on a cable, the cable should be supported as close as possible to the splice. For extensive splicing at section interfaces, it is recommended that individual cable connections be staggered and where appropriate, the cables fanned out from one row to a double row for space to ease installation and avoid derating of cables.

10.3 Important Splicing Factors:

10.3.1 The crimping device shall be matched properly to the splice connector and wire size.
10.3.2 Splicing material should be kept as clean as possible during application so that foreign matter or contaminants are not within the splice. Lightly abrade and solvent clean the cable jacket a minimum of 153 mm (6-in.) from the jacket cutback edge.
10.3.3 Proper installation requires that the shrink tubing should be centered over the installed splice connector, conductor reinsulation material, cable jacket replacement material, and shield braid sleeve connectors, when required.

10.4 Dimensions:

10.4.1 Length of the replacement insulation tubing shall be 57.2 mm (2 1/4 in.) longer than the butt-crimp connector length (see Table 1 and Table 2).
10.4.2 The replacement jacket shall overlap the original cable jacket by either 76.2 or 101.6 mm (3 or 4 in.) min at each end as shown in Fig. 1 or Fig. 2.
10.4.3 Shrink-tubing dimensions shall be as shown in Table 3 for conductor reinsulation or for cable jacket replacement.

10.5 Heating—For heat-shrinkable tubing, apply heat and begin shrinking at the center of the tubes and move toward the ends. For jacket replacement, apply heat at the center of the tube and toward each end until the tube is smooth and wrinkle-free and recovered enough to assume the final configuration. When a fillet of adhesive is visible at each end, discontinue heating. Additional heating will not make the tube shrink tighter.

10.6 Inspection Checkpoints—For quality control and the assurance of a splicing program, there are a number of checkpoints at which inspections can be made to verify proper installation of the cable splice. These include steps in preparation for, during the overall splice process, and post-inspection following completion of a splice.

10.6.1 The following suggests various checkpoints in the splicing process that a quality assurance inspection program could include:

10.6.1.1 Cable ends are properly positioned, that is, staggered configuration and prepared properly to dimensions for size and number of conductors that will be spliced.

10.6.1.2 Splices are assembled properly, positioned in the crimp tool, and crimped.

10.6.1.3 Verify the use of an approved, complete-cycle crimping tool with dies matched to the splice connector and conductor.

10.6.1.4 Verify that the splice connectors are spaced properly.

10.6.1.5 Connectors are insulated properly.

10.6.2 Following conductor insulation replacement, the verification process should include inspection that:

10.6.2.1 All tubings are shrunk in place permanently.

10.6.2.2 All insulation tubings meet the overlap requirements for conductor replacement.

10.6.2.3 Tubings are not nicked or split or charred if heat-shrink tubing was used.

10.6.3 Post-Splice Inspection—Following the completion of a cable splice, post-splice inspections also can be undertaken to check the splice quality. Some checkpoints that should be considered in an inspection program are:

10.6.3.1 Verification that jacket tubing meets the minimum overlap requirements.

10.6.3.2 Verification that the jacket replacement tubing is shrunk permanently in place without damage, such as cut or split.

10.6.3.3 Adhesive should be visible at each end for heat-shrink tubing used in cable sheath replacement.

10.6.3.4 That replacement armor is positioned and secured properly or a jumper is installed to maintain electrical continuity for splices made in armored cable.

10.6.4 For heat-shrink with integral (encased) shield for splicing of shielded cables, the following apply:

10.6.4.1 Sleeve/shield must be recovered along its entire length.

10.6.4.2 Sleeve must be recovered tightly around cable jacket.

10.6.4.3 Sealing rings must have flowed along cable jacket.

10.6.4.4 Sleeve must not have discolored to the degree that joint cannot be inspected.

10.6.4.5 Strands must not be poking through the sleeve.

10.7 Additionally, the shipbuilder has the final inspection checkpoint in that, as part of the standard shipboard tests for cable installations, that is, for continuity and for resistance to ground (insulation resistance), electrical performance of the completed splices shall be tested.

11. Keywords

11.1 cable splicing; crimp connectors; circumferential crimp; electrical cable splicing; insulation sleeving

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL INFORMATION ON CABLE SPLICING SELECTION AND PERFORMANCE CONSIDERATIONS

X1.1 Background

X1.1.1 A number of studies have evaluated available splicing materials and techniques that would support extensive cable splicing mandated in modular ship construction. These investigations affirmed that suitable materials and several installation techniques are available for the various shipboard applications that exist and that these splicing systems would guarantee the integrity of spliced cables to be the equal of a continuously installed cable.

X1.2 Marine Cable

X1.2.1 In the U.S. shipbuilding industry, commercial vessels are constructed typically with IEEE 45-type cables or U.S. Navy military specification cables. Naval combatants and auxiliary ships typically use the Mil Spec cables. Additionally, commercial merchant vessels use a PVC/nylon insulated cable derived from a standard building wire-type construction, as well as a wide variety of nonstandard cables listed by Underwriters Laboratories, Inc. under the Marine Shipboard Cable Program. Foreign vessels typically use cable constructed in accordance with International Electrotechnical Commission (IEC) requirements. These international standards govern the construction and installation of electrical cables on merchant ships and on a general comparison with U.S. practices (IEEE 45 or Mil Spec) are found to be comparable and without significant differences in design.
X1.3 Connectors

X1.3.1 Commercial Versus Military Specification Connectors—A difference in minimum performance requirements of the splice crimp connectors exists between commercial and Mil-Spec-type connectors. The tensile strength requirements for crimped connectors most widely used are those specified in UL 486A or as required in Military Specifications in accordance with MIL-T-7928 or MIL-T-16366.

X1.3.1.1 Comparison of the minimum pull-out force test values listed in these documents shows that, in general, the specified requirements for the Mil-Spec are twice that of the values specified in UL STD 486A.

X1.3.1.2 Tensile strength or minimum pull-out force is the measure of the pulling force required to destroy the crimped connection (joint) between conductors; however, destruction may not necessarily occur at the crimp joint and may occur in one of the following ways:

(a) Slip of the wire from the crimped connector.
(b) Slip of some strands, rupture of the others at the crimp joint.
(c) Rupture of the wire at the crimp joint.
(d) Rupture of the wire outside of the crimped termination.

X1.3.1.3 Although IEEE 45 and the Code of Federal Regulations Title 46 recommends the use of connectors listed by UL STD 486A, this guide adopts that crimp butt connectors used for the marine shipboard environment should have minimum requirements exceeding the basic commercial requirements. The more stringent requirements defined in the military specification certainly are more appropriate to guarantee the mechanical connection between conductors.

X1.3.2 Crimp Configurations—The crimp die of the tool determines the completed crimp configuration. There are a variety of configurations in use, such as a simple nest and indent die, or the more complicated four indent die. Several different configurations may work equally well for some applications, while for others, a certain shape is superior. Since cable splicing for modular construction would require extensive splices at section interfaces for multiple cable runs (banks), therefore, the area (volume of splices) required should be minimized to the maximum extent possible. The optimal technique to fulfill this requirement is the use of the circumferential compression of butt connectors. Circumferential-shaped compression applies equal force around the connector sleeve and results in each conductor strand receiving equal compression and carrying an equal amount of current loading. This type of joint eliminates loose strands, and therefore, is virtually free of electrical-caused noise. In general, connectors compressed into a circumferential joint will have a higher pull-out strength and a lower electrical resistance than the common indented (bathtub) crimped connector. For the best results and to satisfy minimum splice area, a circumferential-shaped compression applying equal force around the sleeve should be used. Note, however, that to assure positive joints, each connector for this type of operation is designed for only one or a very limited number of conductor sizes.

X1.4 Splicing Systems

X1.4.1 The cable splicing method presented in this guide uses a compression-crimp, tubular-metal connector for butt connection of cable conductors in conjunction with the use of shrinkable tubing as both the conductor reinsulating material and overall cable sheath (jacket) replacement. This guide is considered the most effective procedure for the greatest number of applications of cable materials.

X1.4.2 Although other insulating systems are available and considered appropriate for particular applications, they have not been addressed in detail in this guide. The use of various layers of insulating materials, such as shrinkable-tubing, tape, or molding compounds require varying levels of skill, differences in time, and relative cost. The six splicing systems evaluated were:

X1.4.2.1 Cold shrink.
X1.4.2.2 Heat shrink.
X1.4.2.3 Molded—vulcanized.
X1.4.2.4 Molded—resin, room temperature cure.
X1.4.2.5 Molded—resin, heat cure.
X1.4.2.6 Tape.

X1.4.3 The most significant factor that the shipbuilder must address is that the choice of a splicing system must be compatible to both the application/environment and cable jacket material. Information furnished in Tables X1.1-X1.3 provide comparisons for the various splicing systems to application factors, compatibility to cable-jacketing materials, and environment/location of the splice.

X1.4.3.1 Table X1.1 shows compatibility of splicing systems to the various types of cable jacket materials found in shipboard applications.

X1.4.3.2 Acceptability of the six splicing systems with regard to environmental or application location is shown in Table X1.2.

<table>
<thead>
<tr>
<th>Application/Environment</th>
<th>Cold Shrink</th>
<th>Heat Shrink</th>
<th>Molded (Vulcanized)</th>
<th>Resin (Room Temperature Cure)</th>
<th>Resin (Heat Cure)</th>
<th>Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather deck</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Outboard[A]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Enclosed space</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Engine room and machinery space</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Fuel tank (internal)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hazardous areas[A]</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Legend—"Yes" indicates acceptable while "No" indicates not acceptable.

[A] Below water line.
[A] Regulations prohibit splices in hazardous areas.

TABLE X1.1 Splicing System—Application/Environment
X1.4.3.3 Table X1.3 evaluates application factors for the six systems and offers a comparison between systems as to the required skill level of the installer and the time required for installation.

X1.4.4 Shrink Tubing Methods—Shrinkable tubing materials are recommended for the vast majority of cable splice applications. These materials provide the electrical and mechanical properties equivalent to the original cable conductor insulation and jacketing material.

X1.4.4.1 The addition of a sealant is felt necessary since the cable’s jacket may be nonuniform, damaged, or scratched. Deviation from eccentricity or small paths for moisture could lead to splice failure; therefore, the sealant provides an additional safety factor considered necessary. The addition of sealant to the area of overlap on the original cable jacket during splice installation is required for either heat-shrink or cold-shrink tubing.

X1.4.5 Molding Compounds Methods—A variety of materials that includes rubber-based compounds, epoxies, silicones, and polyurethane are available for molded-type cable splices. Vulcanized splices are made with molding presses and require the use of heat. Ambient-temperature cured materials are sometimes referred to as “room temperature” cure since no external heat is applied for the polymerization reactions.

X1.4.5.1 For the marine environment, molded splices mainly are used for outboard, weather-exposed, or underwater applications. This type of splice is molded in matched metal molds, which may be attached to heating platens to expedite forming. For molded splices, the manufacturers’ recommendations on surface cleaning and preparation of the casting compounds and primer should be followed explicitly.

X1.4.6 Tape and Coating Compounds—Taping is more skill/workmanship intensive as compared to the shrinkable tubing or molding compound methods. The basic types of tapes and their primary function is as follows:

X1.4.6.1 Insulating and binder-type tapes are pressure-sensitive tapes used as primary insulation directly over the connector/conductor and as a binder tape over the conductors for cables with two or more conductors. These tapes have a dielectric strength that permits use as a primary insulator over base connectors or conductors.

X1.4.6.2 Filler tape is used both to fill the indents on large connectors and to provide a smooth taping surface over which the cable jacket material can be applied. These tapes have a dielectric strength that permits use as a primary insulator over base connectors or conductors.

X1.4.6.3 Outer sheathing tape is a pressure-sensitive vinyl tape used as sheathing over the filler tape. Sheathing tape is a relatively heavy tape that is used to cover the splice area and provides protection against abrasion and wear.

X1.4.6.4 Care should be exercised to keep adhesive tapes (insulating, binder, and sheathing) clean since they are difficult to remove if they become contaminated with dirt or other foreign materials.

TABLE X1.2 Splicing System—Cable Jacket Compatibility

<table>
<thead>
<tr>
<th>Cable Jacket Compatibility</th>
<th>Cold Shrink</th>
<th>Heat Shrink</th>
<th>Molded (Vulcanized)</th>
<th>Resin (Room Temperature Cure)</th>
<th>Resin (Heat Cure)</th>
<th>Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPDM</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>H.D. polyethylene</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hypalon</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Low halogen polyolefin</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Neoprene</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Nitrile</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PVC</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Silicone</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Legend—“Yes” indicates compatibility while “No” means not compatible.

A Recommendation based on splice not necessarily being of low halogen material.

TABLE X1.3 Comparison of Splicing Systems

<table>
<thead>
<tr>
<th>Application Factors</th>
<th>Cold Shrink</th>
<th>Heat Shrink</th>
<th>Molded (Vulcanized)</th>
<th>Resin (Room Temperature Cure)</th>
<th>Resin (Heat Cure)</th>
<th>Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable preparation</td>
<td>Cut-backs, abrade, solvent wipe</td>
<td>Cut-backs, abrade, solvent wipe</td>
<td>Cut-backs, abrade, solvent wipe</td>
<td>Cut-backs, abrade, solvent wipe</td>
<td>Cut-backs, abrade, solvent wipe</td>
<td>Cut-backs, abrade, solvent wipe</td>
</tr>
<tr>
<td>Application time</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cure time</td>
<td>NA</td>
<td>NA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NA</td>
</tr>
<tr>
<td>Skill level</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2*</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Critical shelf life</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Inspection of installed splice</td>
<td>Centered, adhesive bead</td>
<td>Adhesive bead, bond, centered, burn</td>
<td>Tack-free bond</td>
<td>Tack-free bond</td>
<td>Workmanship, dimensions</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
NA stands for “not applicable.”
Numericals (1 to 5) represent from least (1) to greatest (5).
*—For premeasured resin kit.
Critical shelf life is defined as less than two years.
to apply when the adhesive becomes coated with dirt. Contaminants also will cause degradation to the tape’s electrical properties. All tapes must be applied tightly and smooth and should be applied such that the buildup to reinsulate the individual conductor or produce the overall splice is of uniform cross section.

X1.4.6.5 To complete a tape splice, a coating material, normally a liquid cement compound, shall be brushed on in several thin coats to provide overall seal to the splice.
Standard Specification for Stuffing Tubes, Nylon, and Packing Assemblies (Metric)\textsuperscript{1}

This standard is issued under the fixed designation F 1836M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the general requirements for nylon stuffing tubes and packing assemblies. Nylon stuffing tubes are intended for making electric cable penetrations in marine shipboard enclosures for electrical equipment. The following types are suitable for both thin-wall enclosures up to 5 mm (\(\frac{3}{16}\) in.) thick and thick-wall enclosures, bulkheads, and decks of 5 to 19 mm (\(\frac{3}{16}\) to \(\frac{3}{4}\) in.) thick.

1.2 This specification does not cover metal stuffing tubes.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.

2. Referenced Documents

2.1 ASTM Standards:
D 2000 Classification System for Rubber Products in Automotive Applications\textsuperscript{2}
D 4066 Specification for Nylon Injection and Extrusion Materials (PA)\textsuperscript{3}

2.2 NEMA Standards:
Standard 250 Enclosures for Electrical Equipment (1000 V Max)\textsuperscript{4}

2.3 ASME Standard:
ASME B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)\textsuperscript{5}

2.4 IEC Standard

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 nylon stuffing tube, \(n\) — a marine electrical fitting used for the sealing of cable penetration into shipboard enclosures while maintaining or exceeding the degree of protection for which the enclosure is rated.
3.1.2 packing assembly, \(n\) — the compressible insert for the nylon stuffing tube. It consists of one neoprene bushing and three nylon washers.
3.1.3 enclosure, \(n\) — an electrical panel, cabinet, junction box, light fixture, electrical equipment, control box, or panel.

4. Classification

4.1 Nylon stuffing tubes shall be of the following types (see Fig. 1):
4.1.1 Type 1—straight— Unified Form Thread.
4.1.2 Type 2—90\(^o\) — Unified Form Thread.
4.1.3 Type 3—NPT—American Standard Pipe Thread.
4.1.4 Type 4—Y—Unified Form Thread.

5. Ordering Information

5.1 Orders for stuffing tubes under this specification shall include the following:
5.1.1 Type (see 4.1).
5.1.2 Part number (see Table 1).
5.1.3 Packing assembly size (see Fig. 2 and Table 2).
5.1.4 The O-ring included in the stuffing tube assembly has a finite shelf life. If the stuffing tube assembly is used after the shelf life has expired, the O-ring should be replaced, using the appropriate size listed in Table 1.

6. Materials and Manufacture

6.1 Materials:
6.1.1 Polyamide (nylon) molding plastic material shall be Group 1, Class 8, Grade 1 in accordance with Specification D 4066.
6.1.2 Synthetic rubber (neoprene) shall be in accordance with Classification D 2000, M2, BC, 410, A14, B14, C12, and F19.

6.2 Manufacture:
6.2.1 Molded nylon parts, such as body, washers, locknut, and cap, shall meet the requirements specified herein.

---
\textsuperscript{1} This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.
\textsuperscript{3} Annual Book of ASTM Standards, Vol 09.02.
\textsuperscript{4} Available from the National Electrical Manufacturers Association, 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
\textsuperscript{5} Available from the International Electrotechnical Commission, 3 rue de Varembe, Case postale 131, CH-1211, Geneva 20, Switzerland.
\textsuperscript{6} Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.
6.2.2 Threads shall be unified form UN 2A or 2B or taper pipe thread (NPT) as specified in ASME Standard B1.1.

6.2.3 Neoprene parts, such as bushing and plug, shall meet the requirements specified in Classification D 2000, and when assembled in a stuffing tube, shall meet the performance requirements specified herein.

7. Other Requirements

7.1 Performance Requirements:

7.1.1 Vibration resistance—When stuffing tubes are tested as specified in 9.1, there shall be no evidence of cracking or loosening of parts.

7.1.2 Ruggedness—When stuffing tubes are subjected to a mechanical abuse test as specified in 9.2, there shall be no cracking, breaking, distortion, or damage to the sample.

7.1.3 Effectiveness of seal—When stuffing tubes are tested as specified in 9.3, there shall be no evidence of leakage through or around the stuffing tubes.

8. Workmanship, Finish, and Appearance

8.1 Stuffing tubes shall be free from warp, cracks, chipped edges or surfaces, blisters, uneven surfaces, scratches, dents, and heat marks. They shall be free from fins, burrs, and unsightly finish caused by chipping, filing, or grinding without subsequent buffing or polishing. All molded nylon parts shall
be cleaned thoroughly of annealing mediums. Packing assemblies shall be free of voids, pin holes, flash, or other imperfections, that may impair their serviceability.

### 9. Test Methods

9.1 Conformance testing of a random sample may be requested by the purchaser to verify that selected performance characteristics specified herein have been incorporated in the stuffing tube design and maintained in production.

9.1.1 Vibration—The stuffing tubes shall be subjected to vibration testing as specified in IEC Standard 68-2-6. The following details shall apply:

9.1.1.1 The stuffing tubes shall be complete with O-rings and 1- to 2-m (3- to 6-ft) lengths of cable of appropriate size.

9.1.1.2 The free end of the cables shall be secured to prevent excessive cable whipping action during test.

### Table 1: Stuffing Tubes Part Numbers and Dimensional Data

<table>
<thead>
<tr>
<th>Tube Size</th>
<th>Part No.</th>
<th>Cable Range</th>
<th>Packing</th>
<th>Clearance Hole Diameter</th>
<th>O-Ring Assembly</th>
<th>Buna-N Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type-1-001</td>
<td>0.077 - 0.300</td>
<td>1.96 - 7.62</td>
<td>-16</td>
<td>0.885 - 22.48</td>
<td>212</td>
</tr>
<tr>
<td>2</td>
<td>-002</td>
<td>0.275 - 0.472</td>
<td>6.99 - 11.99</td>
<td>-17</td>
<td>1.010 - 25.65</td>
<td>214</td>
</tr>
<tr>
<td>3</td>
<td>-003</td>
<td>0.410 - 0.472</td>
<td>10.41 - 11.99</td>
<td>-18</td>
<td>1.135 - 28.83</td>
<td>216</td>
</tr>
<tr>
<td>4</td>
<td>-004</td>
<td>0.450 - 0.777</td>
<td>11.43 - 19.74</td>
<td>-19</td>
<td>1.260 - 32.00</td>
<td>218</td>
</tr>
<tr>
<td>5</td>
<td>-005</td>
<td>0.450 - 0.777</td>
<td>11.43 - 19.74</td>
<td>-19</td>
<td>1.385 - 35.18</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>-006</td>
<td>0.752 - 1.113</td>
<td>19.10 - 28.27</td>
<td>-20</td>
<td>2.010 - 51.05</td>
<td>226</td>
</tr>
<tr>
<td>7</td>
<td>-007</td>
<td>0.806 - 1.390</td>
<td>20.47 - 35.31</td>
<td>-21</td>
<td>2.510 - 63.75</td>
<td>230</td>
</tr>
<tr>
<td>8</td>
<td>-008</td>
<td>1.433 - 1.610</td>
<td>36.40 - 40.89</td>
<td>-22</td>
<td>2.760 - 70.10</td>
<td>232</td>
</tr>
<tr>
<td>9</td>
<td>-010</td>
<td>2.030 - 2.700</td>
<td>51.56 - 68.58</td>
<td>-24</td>
<td>4.010 - 101.85</td>
<td>242</td>
</tr>
</tbody>
</table>

#### Table 2: Stuffing Tubes Part Numbers and Dimensional Data

<table>
<thead>
<tr>
<th>Tube Size</th>
<th>Part No.</th>
<th>Cable Range</th>
<th>Packing</th>
<th>Clearance Hole Diameter</th>
<th>O-Ring Assembly</th>
<th>Buna-N Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type-2-001</td>
<td>0.077 - 0.300</td>
<td>1.96 - 7.62</td>
<td>-16</td>
<td>0.885 - 22.48</td>
<td>212</td>
</tr>
<tr>
<td>2</td>
<td>-002</td>
<td>0.275 - 0.472</td>
<td>6.99 - 11.99</td>
<td>-17</td>
<td>1.010 - 25.65</td>
<td>214</td>
</tr>
<tr>
<td>3</td>
<td>-003</td>
<td>0.410 - 0.472</td>
<td>10.41 - 11.99</td>
<td>-18</td>
<td>1.135 - 28.83</td>
<td>216</td>
</tr>
<tr>
<td>4</td>
<td>-004</td>
<td>0.450 - 0.777</td>
<td>11.43 - 19.74</td>
<td>-19</td>
<td>1.260 - 32.00</td>
<td>218</td>
</tr>
<tr>
<td>5</td>
<td>-005</td>
<td>0.450 - 0.777</td>
<td>11.43 - 19.74</td>
<td>-19</td>
<td>1.385 - 35.18</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>-006</td>
<td>0.752 - 1.113</td>
<td>19.10 - 28.27</td>
<td>-20</td>
<td>2.010 - 51.05</td>
<td>226</td>
</tr>
<tr>
<td>7</td>
<td>-007</td>
<td>0.806 - 1.390</td>
<td>20.47 - 35.31</td>
<td>-21</td>
<td>2.510 - 63.75</td>
<td>230</td>
</tr>
</tbody>
</table>

#### Table 3: Stuffing Tubes Part Numbers and Dimensional Data

<table>
<thead>
<tr>
<th>Tube Size</th>
<th>Part No.</th>
<th>Cable Range</th>
<th>Packing</th>
<th>Clearance Hole Diameter</th>
<th>O-Ring Assembly</th>
<th>Buna-N Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type-3-001</td>
<td>0.077 - 0.300</td>
<td>1.96 - 7.62</td>
<td>-16</td>
<td>0.5 - 0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>-002</td>
<td>0.275 - 0.472</td>
<td>6.99 - 11.99</td>
<td>-17</td>
<td>0.75 - 0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>3</td>
<td>-003</td>
<td>0.410 - 0.472</td>
<td>10.41 - 11.99</td>
<td>-18</td>
<td>1.0 - 1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>-004</td>
<td>0.450 - 0.777</td>
<td>11.43 - 19.74</td>
<td>-19</td>
<td>1.5 - 1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>-005</td>
<td>0.752 - 1.113</td>
<td>19.10 - 28.27</td>
<td>-20</td>
<td>2 - 2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>-006</td>
<td>0.806 - 1.390</td>
<td>20.47 - 35.31</td>
<td>-21</td>
<td>2.5 - 2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>7</td>
<td>-007</td>
<td>1.433 - 1.610</td>
<td>36.40 - 40.89</td>
<td>-22</td>
<td>3 - 3</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>-008</td>
<td>1.625 - 2.00</td>
<td>41.28 - 50.80</td>
<td>-23</td>
<td>3 - 3</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>-009</td>
<td>2.030 - 2.700</td>
<td>51.56 - 68.58</td>
<td>-24</td>
<td>3.5 - 3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

#### Table 4: Stuffing Tubes Part Numbers and Dimensional Data

<table>
<thead>
<tr>
<th>Tube Size</th>
<th>Part No.</th>
<th>Cable Ranges</th>
<th>Packing</th>
<th>Clearance Hole Diameter</th>
<th>O-Ring Assembly</th>
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<td>0.450 - 0.777</td>
<td>11.43 - 19.74</td>
<td>-19</td>
<td>1.385 - 35.18</td>
<td>220</td>
</tr>
</tbody>
</table>

<fig:2 Typical Packing Assembly>

A See Table 2 size selection.
9.1.1.3 Tests are to be carried out in three perpendicular planes.

9.1.1.4 Duration of the test for no resonance condition shall be 90 min at 30 Hz. Duration at each resonance frequency at which \( Q > 2 \) is recorded. It is recommended as guidance that \( Q \) does not exceed 5.

9.1.1.5 Test range shall be:

- \( 2^{60.3} \) to 13.2 Hz – amplitude \( 6^{1} \) mm
- 13.2 to 100 Hz – acceleration \( 6^{7} \) g

9.1.1.6 Nonconformance to the requirements of 7.1.1 shall be cause for rejection.

9.2 Mechanical Abuse Test:

9.2.1 Mechanical abuse test shall be conducted on the sample stuffing tubes assembled with packing assembly on the end of a 2-m (6-ft) length of electrical cable of appropriate size.

9.2.2 The stuffing tube shall be allowed to swing on a radius, while suspended by the electrical cable, from a vertical surface and strike against a vertical flat steel plate on that surface. The vertical distance through which the stuffing tube is allowed to fall shall be 1.5 m (5 ft), and the number of impacts shall be ten.

9.2.3 The stuffing tube shall be disassembled and examined. Nonconformance to the requirements of 7.1.1 shall be cause for rejection.

9.3 Level of Effectiveness—A complete stuffing tube with O-ring installed and properly assembled to a cable or with a plug installed shall conform to the performance requirements of NEMA 250. The NEMA enclosure-type designation (4, 4X, 6, 6P) shall establish the appropriate environmental capability (see NEMA 250) required of the installed stuffing tube assembly.

9.3.1 Nonconformance to the requirements of 7.1.3 shall be cause for rejection.

10. Inspection

10.1 Visual and Dimensional Examination—Samples shall be examined visually to verify that the materials, design, construction, physical dimensions, marking, and workmanship are as specified in the applicable requirements.

11. Certification

11.1 Plastic Material Certification—Material certification shall be required from the manufacturer of the plastic material to ensure the material was manufactured, sampled, tested, and inspected in accordance with Specification D 4066. Material identity, traceable to this certification, shall be maintained throughout the manufacturing process.

11.2 Cure date information of all rubber products shall be recorded on the manufacturer’s certificate of conformance. The year and quarter of manufacture shall be listed.

### TABLE 2 Packing Assembly Size

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**Note 1**—Packing assembly selection requires that the packing bushing inner diameter (\( D \)) be equal or slightly larger than the cable maximum diameter (DIA).

**Note 2**—I.D. column indicates the bushing inner diameter.
11.3 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12. Product Marking

12.1 Each nylon stuffing tube component body, locknut, cap, bushing, and washers shall have permanent marking in 3-mm (1/8-in.) high raised letters as size permits. For size-sensitive components, reduced marking is acceptable. Marking shall indicate the following:

12.1.1 Manufacturer’s name or trademark and tube size.

12.1.2 Identification markings of prior or superseded specifications or government drawings. These markings are acceptable. New molds or molds that require rework shall contain, if required, the ASTM designation number of this specification and part number. The location of the ASTM marking shall apply to the stuffing tube only and be located on the stuffing tube body. Marking in accordance with 12.1.1 shall apply to all stuffing tube components.

13. Packaging

13.1 Packaging shall be manufacturer’s commercial practice and shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the manufacturer or supplier, or both, to the using activity.

Note 1—Bulk packaging for nylon stuffing tubes; unit packaging for packing assemblies.

14. Quality Assurance

14.1 Responsibility for Inspection—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other facilities suitable for the performance of the inspection requirements specified.

14.2 Responsibility for Compliance—All items must meet all the requirements of Section 7. The inspection set forth in this specification shall become a part of the manufacturer’s overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the manufacturer of the responsibility of assuring that all products or supplies submitted to the customer for acceptance comply with all the requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material either indicated or actual, nor does it commit the purchaser to acceptance of defective material.

15. Keywords

15.1 cable entry seal; cable penetrator; stuffing tube

**SUPPLEMENTARY REQUIREMENTS**

The following supplementary requirements are applicable to DoD procurements and shall apply only when specified by the purchaser in the contract or purchase order.

S1. Referenced Documents

S1.1 Military Specifications:
MIL-S-901 Requirements for Shock Tests, H.I. (High-Impact), Shipboard Machinery, Equipment, and Systems

S2. Shock Tests

S2.1 Stuffing tubes shall be subjected to the high-impact shock test for Grade A, Type A, Class I equipment as specified in MIL-S-901. The details specified in 9.1 and 9.2 shall apply. Nonconformance to the requirements of S2.2 shall be cause for rejection.

S2.2 Examination After Shock Tests—When stuffing tubes are tested as specified in S2.1, there shall be no evidence of cracking, breaking, distortion, or loosening of parts.

S3. Level of Effectiveness (See 9.3)

S3.1 Submersible and Open Submersible—Equipment shall be submergence tested to a depth of 4.5 m (15 ft) at 44.8 KPa (6.5 psi) for 24 h. Nonconformance to the requirements of 7.1.3 shall be cause for rejection.

S3.2 Examination After Immersion—Failure for stuffing tube to operate satisfactorily shall be cause for rejection. For enclosures including terminal boxes, as revealed by subsequent disassembly and examination, leakage of water into any part of the enclosure shall be cause for rejection.

S4. Packaging

S4.1 Preservation, Packing, and Marking—Preservation and packing may be commercial. Marking information shall include cure date, shelf life, and expiration dates of rubber products.
Standard Specification for
Heat-Shrink Cable Entry Seals (Metric)¹

This standard is issued under the fixed designation F 1837M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the general requirements for heat-shrink cable entry seals. Cable entry seals are intended for making electrical cable penetrations into connection boxes, bulkheads, or other enclosures. These devices are suitable for both thin wall enclosures up to 5 mm (3⁄16 in.) thick and thick-wall enclosures of 5 mm to 19 mm (3⁄16 in. to 3⁄4 in.) thick.

1.2 Cable entry seals shall have factory-applied adhesive that provides the seal to wire and cable jackets.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.

2. Referenced Documents

2.1 ASTM Standards:
D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies²
D 257 Test Methods for DC Resistance to Conductance of Insulating Materials²
D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers³
D 570 Test Method for Water Absorption of Plastics⁴
D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position⁴
D 747 Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam⁴
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement⁴
D 2240 Test Methods for Rubber Property—Durometer Hardness³

D 2671 Test Methods for Heat-Shrinkable Tubing for Electrical Use⁵
D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)⁶
D 3149 Specification for Crosslinked Polyolefin Heat-Shrinkable Tubing for Electrical Insulation⁵
D 4572 Test Method for Rubber Chemicals, Wet Sieve Analysis of Sulfur³
D 4732 Specification for Cool-Application Filling Compounds for Telecommunication Wire and Cable

2.2 ASME Standard
ASME B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)⁷

2.3 NEMA Standards:⁵
NEMA 250 Enclosures for Electrical Equipment (1000 Volts Max)⁸

2.4 IEC Standard:

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 heat-shrink cable entry seal, n—heat-shrinkable tube making a watertight, fume-tight seal where cable connections boxes, bulkheads, or other enclosures.

3.1.2 polyolefin, n—a polymer made by the polymerization of hydrocarbon olefins or copolymerization olefins.

4. Classification

4.1 Heat-shrink cable entry seals shall be of the following types:

4.1.1 Type I, standard cable entry seals for thin-wall enclosures shall consist of the three part assembly; a rigid plastic nut, O-ring, and heat-shrinkable molded area.

4.1.1.1 Type I–1, molded area configured with one opening for a single wire or cable entry.

---

¹ This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.
⁴ Annual Book of ASTM Standards, Vol 09.01.
⁵ Annual Book of ASTM Standards, Vol 08.01.
⁶ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.
⁷ Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
⁸ Available from International Electrotechnical Commission (IEC), 3, rue de Varembe, Case Postale 131, CH-1211, Geneva 20, Switzerland.

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4.1.1.2 Type I–2, molded area configured with two equal size openings to seal two wires or cables.
4.1.1.3 Type I–3, molded area configured with three equal size openings to seal three wires or cables.
4.1.1.4 Type I–4, molded area configured with four equal size openings to seal four wires or cables.
4.1.1.5 Type I–5, molded area configured with six equal size openings to seal six wires or cables.
4.1.1.6 Type I–6, molded area configured with eight equal size openings to seal eight wires or cables.
4.1.2 Type II, cable entry seal for threaded hole applications shall consist of a one-part assembly that combines a tapered national pipe thread (NPT) in rigid plastic with heat-shrinkable molded area.
4.1.2.1 Type II–1, molded area configured with one opening for a single wire or cable entry.
4.1.2.2 Type II–2, molded area configured with two equal size openings to seal two wires or cables.
4.1.2.3 Type II–3, molded area configured with three equal size openings to seal three wires or cables.
4.1.2.4 Type II–4, molded area configured with four equal size openings to seal four wires or cables.
4.1.3 Type III, right angle cable entry seal for thin-wall enclosure shall consist of a three part assembly; a rigid plastic nut, O-ring, and heat-shrinkable molded area.
4.1.4 Type IV, right angle cable entry seal for threaded hole application shall consist of a one-part assembly that combines a tapered national pipe thread (NPT) in rigid plastic with a heat-shrinkable molded area.

5. Ordering Information
5.1 Orders for cable entry seals under this specification shall include the following:
5.1.1 Part Number (see Figs. 1-6).
5.1.2 Quantity (per each part).

6. Materials and Manufacture
6.1 The rigid plastic parts shall be made from polyamide (nylon), (or polyester material, or both.) The material shall be Group 1, Class 8, Grade 1 as specified in Specification D 4066.
6.1.1 Threads shall be unified form UN 2A or 2B or taper pipe thread (NPT) as specified in ASME B1. 1.
6.2 The heat-shrinkable tubing shall be of a crosslinked polyolefin in accordance with Type III of Specification D 3149.
6.3 The adhesive shall be general purpose high-bond-strength adhesive sealant that provides stain relief and environmental sealing of heat-shrink tubing to cable jackets.

6.4 O-rings shall be made of a material conforming to Type II of Specification D 4732.
6.5 The polyolefin heat-shrinkable tubing shall meet requirements of Test Methods D 2671.

7. Other Requirements
7.1 Dimensional Requirements—Cable-entry seals shall conform to the dimensional requirements of Tables 1-6. Type I cable-entry seals are presented in Fig. 1 and Fig. 2. Type II cable-entry seals are presented in Fig. 3 and Fig. 4. Right-angle cable-entry seals (Types III and IV) are presented in Fig. 5 and Fig. 6.
7.2 Performance Requirements:
7.2.1 Vibration Resistance—When cable-entry seals are tested as specified in 9.1, there shall be no evidence of cracking or loosening of parts.
7.2.2 Ruggedness—When cable-entry seals are subjected to a mechanical abuse test as specified in 9.2, there shall be no cracking, breaking, distortion, or damage to the sample.
7.2.3 Effectiveness of seal—When cable-entry seals are tested as specified in 9.3, there shall be no evidence of leakage through or around the cable entry seals.

8. Workmanship, Finish, and Appearance
8.1 Cable-entry seals shall be free from warp, cracks, chipped edges, or surfaces, blisters, uneven surfaces, scratches, dents, and flow lines. They shall be free from fins, burrs, and from unsightly finish caused by chipping, filling, or grinding without subsequent buffing or polishing. All molded parts shall cleaned thoroughly of annealing mediums.

9. Test Methods
9.1 Conformance testing of a random sample may be requested by the purchaser in order to verify that selected performance characteristics specified herein have been incorporated in the cable-entry seal design and maintained in production.
9.1.1 Vibration—The cable-entry seals shall be subjected to vibration testing as specified in IEC Standard 68-2-6. The following details shall apply:
9.1.1.1 The cable-entry seals shall be complete with O-rings and 1 to 2-m (3 to 6 ft) lengths of cable of appropriate size.
9.1.1.2 The free end of the cables shall be secured to prevent excessive cable whipping action during test.
9.1.1.3 Tests are to be carried out in three perpendicular planes.
9.1.1.4 Duration of the test for no resonance condition shall be 90 min at 30 Hz. Duration at each resonance frequency at which Q>2 is recorded. It is recommended as guidance that Q does not exceed 5.
9.1.1.5 Test range shall be 2 ± 0.3 Hz to 13.2 Hz–amplitude ± 1 mm; 13.2 Hz to 100 Hz–acceleration ±7 g.
9.1.1.6 Nonconformance to the requirements of 7.2.1 shall be cause for rejection.
9.2 Mechanical Abuse Test:
9.2.1 A mechanical abuse test shall be conducted on the sample cable-entry seal assembled on the end of a 2-m (6-ft) length of electrical cable of appropriate size.
9.2.2 The cable-entry seal shall be allowed to swing on a radius, while suspended by the electrical cable, from a vertical surface and strike against a vertical flat steel plate on that surface. The vertical distance through which the cable entry seal is allowed to fall shall be 1.5 m (5 ft), and the number of impacts shall be ten.

9.2.3 The cable-entry seal shall be disassembled and examined. Nonconformance to the requirements of 7.2.2 shall be cause for rejection.

9.3 Level of Effectiveness—A complete cable-entry seal with O-ring installed and assembled properly and shrunk to a cable or with a plug installed shall conform to the performance requirements of NEMA 250. The NEMA enclosure type designation (4, 4X, 6, 6P) shall establish the appropriate environmental capability required of the installed cable-entry seal.

9.3.1 Nonconformance to the requirements of 7.2.3 shall be cause for rejection.

10. Inspection

10.1 Visual and Dimensional Examination—Samples shall be examined visually to verify that the materials, design, construction, physical dimensions, marking, and workmanship are as specified in the applicable requirements.

11. Certification

11.1 Material Certification—Material certification shall be required from the manufacturers of the plastic material and shirk-tubing to ensure the materials were manufactured, sampled, tested, and inspected in accordance with Specifications D 4066 and D 3149. Material identity traceable to this certification shall be maintained throughout the manufacturing process.

11.2 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.
specified in the purchase order or contract, a report of the test results shall be furnished.

12. Product Marking

12.1 Each cable-entry seal shall be identified distinctly. The name of the manufacturer, part number, identification of this ASTM standard, and other appropriate information shall be shown thereon.

13. Packaging Requirements

13.1 The seals shall be supplied by type as specified in Figs. 1-6.

13.2 The seals shall be packaged in conformance with good commercial practice unless otherwise specified. Individual types and sizes shall be neatly bundled or boxed. The exterior shipping container shall be acceptable by parcel post or common carrier.

13.3 Each bundle or container of seals shall be identified distinctly by a tag or label. The name of the manufacturer, the part number of the seals, the quantity, and other appropriate information shall be shown thereon.

14. Quality Assurance

14.1 Responsibility for Inspection—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own
14. Responsibility for Compliance

—All items must meet all requirements of section 7. The inspection set forth in this specification shall become a part of the manufacturer’s overall inspection system or quality program. The absence of any inspection requirements in this specification shall not relieve the manufacturer of the responsibility of assuring that all products or supplied submitted to the customer for acceptance comply with all the requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material either indicated or actual, nor does it commit the customer to acceptance of defective material.

15. Keywords

—15.1 cable-entry seal; cable penetrator; cable termination; cross-linked polyolefin heat-shrinkable tubing; electrical insulation; heat-shrinkable tubing

### TABLE 1 Type 1—Single Legged Standard Cable Entry Seals

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<td>(max)</td>
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<td>40.0 (1.70)</td>
<td>19.0 (0.75)</td>
<td>40.0 (1.60)</td>
</tr>
<tr>
<td>70.0 (2.75)</td>
<td>19.0 (0.75)</td>
<td>53.0 (2.10)</td>
</tr>
<tr>
<td>70.0 (2.75)</td>
<td>36.0 (1.43)</td>
<td>74.0 (2.90)</td>
</tr>
</tbody>
</table>

- Dimensions shown are nominal and in millimeters (in).
- Part numbers were established in the following way:
  - CES—cable entry seal,
  - S or T—standard or threaded, and
  - 1-1—number preceding hyphen represents number legs; number following hyphen represents size type.

### TABLE 2 Type 1—Multi-Legged Standard Cable Entry Seals

<table>
<thead>
<tr>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-Leg Boot</td>
<td></td>
</tr>
<tr>
<td>Expanding I.D.</td>
<td>Recovered I.D.</td>
</tr>
<tr>
<td>Min. (Each Leg)</td>
<td>Max. (Each Leg)</td>
</tr>
<tr>
<td>I.D. (min)</td>
<td>Overall Nominal Recovered Length</td>
</tr>
<tr>
<td>Part No.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10.0 (0.40)</td>
</tr>
<tr>
<td>2</td>
<td>15.0 (0.60)</td>
</tr>
<tr>
<td>3</td>
<td>10.0 (0.40)</td>
</tr>
<tr>
<td>3</td>
<td>15.0 (0.60)</td>
</tr>
<tr>
<td>3</td>
<td>23.0 (0.90)</td>
</tr>
<tr>
<td>3</td>
<td>32.0 (1.25)</td>
</tr>
<tr>
<td>4</td>
<td>15.0 (0.60)</td>
</tr>
<tr>
<td>4</td>
<td>23.0 (0.90)</td>
</tr>
<tr>
<td>4</td>
<td>32.0 (1.25)</td>
</tr>
<tr>
<td>6</td>
<td>23.0 (0.90)</td>
</tr>
<tr>
<td>8</td>
<td>23.0 (0.90)</td>
</tr>
</tbody>
</table>

- Dimensions shown are nominal and in millimeters (inches).
- Part numbers were established in the following way:
  - CES—cable entry seal,
  - S or T—standard or threaded, and
  - 1-1—number preceding hyphen represents number of legs; number following hyphen represents size type.

or any other facilities suitable for the performance of the inspection requirements specified.

14.2 Responsibility for Compliance—All items must meet all requirements of section 7. The inspection set forth in this specification shall become a part of the manufacturer’s overall inspection system or quality program. The absence of any inspection requirements in this specification shall not relieve the manufacturer of the responsibility of assuring that all products or supplied submitted to the customer for acceptance.
### TABLE 3 Type II—Single-Legged Threaded Cable Entry Seals

<table>
<thead>
<tr>
<th>tubing</th>
<th>expanded I.D. (min.)</th>
<th>recovered I.D. (max.)</th>
<th>overall nominal recovered length</th>
<th>NPT pipe size</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CST T 1-1</td>
<td>9.5 (0.37)</td>
<td>3.0 (0.12)</td>
<td>6.5 (0.25)</td>
<td>87.0 (3.40)</td>
<td>6.5 (0.25)</td>
</tr>
<tr>
<td>CES T 1-2</td>
<td>14.5 (0.57)</td>
<td>5.0 (0.19)</td>
<td>14.0 (0.55)</td>
<td>87.0 (3.40)</td>
<td>13.0 (0.50)</td>
</tr>
<tr>
<td>CES T 1-3</td>
<td>19.0 (0.75)</td>
<td>6.5 (0.25)</td>
<td>19.0 (0.75)</td>
<td>87.0 (3.40)</td>
<td>19.0 (0.75)</td>
</tr>
<tr>
<td>CES T 1-4</td>
<td>19.0 (0.75)</td>
<td>6.5 (0.25)</td>
<td>19.0 (0.75)</td>
<td>89.0 (3.50)</td>
<td>25.5 (1.00)</td>
</tr>
<tr>
<td>CES T 1-5</td>
<td>32.0 (1.25)</td>
<td>13.0 (0.50)</td>
<td>25.5 (1.00)</td>
<td>112.0 (4.40)</td>
<td>25.5 (1.00)</td>
</tr>
<tr>
<td>CES T 1-6</td>
<td>32.0 (1.25)</td>
<td>13.0 (0.50)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
<td>38.0 (1.50)</td>
</tr>
<tr>
<td>CES T 1-7</td>
<td>51.0 (2.00)</td>
<td>19.0 (0.75)</td>
<td>36.0 (1.40)</td>
<td>127.0 (5.00)</td>
<td>38.0 (1.50)</td>
</tr>
<tr>
<td>CES T 1-8</td>
<td>70.0 (2.75)</td>
<td>25.5 (1.00)</td>
<td>61.0 (2.40)</td>
<td>152.0 (6.00)</td>
<td>63.5 (2.50)</td>
</tr>
</tbody>
</table>

Note: Dimensions shown are nominal and in the millimeters (inches).

Part numbers were established in the following way:
- CES—cable entry seal,
- S or T—standard or threaded,
- 1—number preceding hyphen represents number of legs; number following hyphen represents size type.

### TABLE 4 Type II—Multi-Legged Threaded Cable Entry Seals

<table>
<thead>
<tr>
<th>multi-leg boot</th>
<th>expanded I.D. (min.)</th>
<th>recovered I.D. (max.)</th>
<th>overall nominal recovered length</th>
<th>NPT pipe size</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CST T 2-1</td>
<td>2</td>
<td>10.0 (0.40)</td>
<td>3.0 (0.11)</td>
<td>14.0 (0.55)</td>
<td>87.0 (3.40)</td>
</tr>
<tr>
<td>CES T 2-2</td>
<td>2</td>
<td>10.0 (0.40)</td>
<td>3.0 (0.11)</td>
<td>19.0 (0.75)</td>
<td>87.0 (3.40)</td>
</tr>
<tr>
<td>CES T 2-3</td>
<td>2</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>112.0 (4.40)</td>
</tr>
<tr>
<td>CES T 2-4</td>
<td>2</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 2-5</td>
<td>2</td>
<td>23.0 (0.90)</td>
<td>7.5 (0.30)</td>
<td>37.0 (1.47)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 2-6</td>
<td>2</td>
<td>10.0 (0.40)</td>
<td>3.0 (0.11)</td>
<td>14.0 (0.55)</td>
<td>95.0 (3.75)</td>
</tr>
<tr>
<td>CES T 2-7</td>
<td>2</td>
<td>10.0 (0.40)</td>
<td>3.0 (0.11)</td>
<td>19.0 (0.75)</td>
<td>94.0 (3.70)</td>
</tr>
<tr>
<td>CES T 2-8</td>
<td>2</td>
<td>10.0 (0.40)</td>
<td>3.0 (0.11)</td>
<td>19.0 (0.75)</td>
<td>95.0 (3.75)</td>
</tr>
<tr>
<td>CES T 2-9</td>
<td>3</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>112.0 (4.40)</td>
</tr>
<tr>
<td>CES T 3-1</td>
<td>3</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 3-2</td>
<td>3</td>
<td>23.0 (0.90)</td>
<td>7.5 (0.30)</td>
<td>37.0 (1.47)</td>
<td>127.0 (5.00)</td>
</tr>
<tr>
<td>CES T 3-3</td>
<td>3</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 3-4</td>
<td>3</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 3-5</td>
<td>3</td>
<td>23.0 (0.90)</td>
<td>7.5 (0.30)</td>
<td>37.0 (1.47)</td>
<td>127.0 (5.00)</td>
</tr>
<tr>
<td>CES T 3-6</td>
<td>3</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 3-7</td>
<td>3</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 3-8</td>
<td>4</td>
<td>10.0 (0.40)</td>
<td>3.0 (0.11)</td>
<td>19.0 (0.75)</td>
<td>87.0 (3.40)</td>
</tr>
<tr>
<td>CES T 3-9</td>
<td>4</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>112.0 (4.40)</td>
</tr>
<tr>
<td>CES T 4-1</td>
<td>4</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 4-2</td>
<td>4</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 4-3</td>
<td>4</td>
<td>15.0 (0.60)</td>
<td>4.5 (0.18)</td>
<td>28.0 (1.10)</td>
<td>119.0 (4.70)</td>
</tr>
<tr>
<td>CES T 4-4</td>
<td>4</td>
<td>23.0 (0.90)</td>
<td>7.5 (0.30)</td>
<td>37.0 (1.47)</td>
<td>127.0 (5.00)</td>
</tr>
<tr>
<td>CES T 4-5</td>
<td>4</td>
<td>32.0 (1.25)</td>
<td>13.0 (0.50)</td>
<td>61.0 (2.40)</td>
<td>152.0 (6.00)</td>
</tr>
<tr>
<td>CES T 4-6</td>
<td>4</td>
<td>32.0 (1.25)</td>
<td>13.0 (0.50)</td>
<td>61.0 (2.40)</td>
<td>152.0 (6.00)</td>
</tr>
</tbody>
</table>

Note: Dimensions shown are nominal and in millimeters (inches).

Part numbers were established in the following way:
- CES—cable entry seal and
- S or T—standard or threaded.
TABLE 5 Type III—Right Angle Cable Entry Seals

<table>
<thead>
<tr>
<th>Tubing</th>
<th>B</th>
<th>A</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded I.D. (min.)</td>
<td>Recovered I.D. (max.)</td>
<td>I.D. (min.)</td>
<td>Overall Nominal Recovered Length</td>
</tr>
<tr>
<td>14.0 (0.55)</td>
<td>7.0 (0.28)</td>
<td>14.0 (0.55)</td>
<td>36.0 (1.40)</td>
</tr>
<tr>
<td>19.0 (0.75)</td>
<td>8.5 (0.33)</td>
<td>19.0 (0.75)</td>
<td>43.0 (1.70)</td>
</tr>
<tr>
<td>28.0 (1.10)</td>
<td>16.0 (0.62)</td>
<td>28.0 (1.10)</td>
<td>79.0 (3.10)</td>
</tr>
<tr>
<td>40.0 (1.60)</td>
<td>16.0 (0.62)</td>
<td>40.0 (1.60)</td>
<td>79.0 (3.10)</td>
</tr>
</tbody>
</table>

\(^a\) Dimensions shown are nominal and in millimeters (inches).
\(^b\) Part numbers were established in the following way:
CES—cable entry seal,
S or T—standard or threaded, and
R-1—Right angle; number following hyphen represents size type.

TABLE 6 Type IV—Right Angle Cable Entry Seals

<table>
<thead>
<tr>
<th>Tubing</th>
<th>B</th>
<th>A</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded I.D. (min.)</td>
<td>Recovered I.D. (max.)</td>
<td>I.D. (min.)</td>
<td>Overall Nominal Recovered Length</td>
</tr>
<tr>
<td>14.0 (0.55)</td>
<td>7.0 (0.28)</td>
<td>14.0 (0.55)</td>
<td>36.0 (1.40)</td>
</tr>
<tr>
<td>19.0 (0.75)</td>
<td>8.5 (0.33)</td>
<td>19.0 (0.75)</td>
<td>43.0 (1.70)</td>
</tr>
<tr>
<td>25.5 (1.00)</td>
<td>10.0 (0.38)</td>
<td>25.5 (1.00)</td>
<td>79.0 (3.10)</td>
</tr>
<tr>
<td>28.0 (1.10)</td>
<td>16.0 (0.62)</td>
<td>28.0 (1.10)</td>
<td>79.0 (3.10)</td>
</tr>
</tbody>
</table>

\(^a\) Dimensions shown are nominal and in millimeters (inches).
\(^b\) Part numbers were established in the following way:
CES—cable entry seal,
S or T—standard or threaded, and
R-1—Right angle; number following hyphen represents size type.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are applicable to DoD procurements and shall apply only when specified by the purchaser in the contract or purchase order.

S1. Referenced Documents
S.1.1 Military Specification:
MIL-S-901 Shock Tests, H.I. (High-Impact), Shipboard Machinery, Equipment, and Systems\(^{10}\)

S2. Shock Tests
S2.1 Cable-entry seals shall be subjected to the high-impact shock test for Grade A, Type A, Class I equipment as specified in MIL-S-901. The details specified in 9.1.1 and 9.1.2 shall apply. Nonconformance to the requirements of S2.2 shall be cause for rejection.

S2.2 Examination After Shock Tests—When cable-entry seals are tested as specified in S.2.1, there shall be no evidence of cracking, breaking, distortion, or loosening of parts.

S3. Performance Requirements
S3.1 Table S3.1 establishes the physical, thermal, and chemical properties for heat-shrink tubing used in the cable-entry seal.

S4. Level of Effectiveness (See 9.3)
S4.1 Submersible and Open Submersible—Equipment shall be submersion tested to a depth of 4.5 m (15 ft) at 44.8 KPa (6.5 psi) for 24 h. Nonconformance to the requirements of 7.1.3 shall be cause for rejection.

S4.2 Examination After Immersion—Failure for cable-entry seals to operate satisfactorily shall be cause for rejection. For enclosures including terminal boxes, as revealed by subsequent

\(^{10}\) Available from the Standardization Document Order Desk, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111–5098.
disassembly and examination leakage of water into any part of the enclosure, shall be cause for rejection.

S5. Packaging

S5.1 Preservation, Packing, and Marking—Preservation and packing may be commercial. Marking information shall in-
Standard Guide for 
Escort Vessel Evaluation and Selection

This standard is issued under the fixed designation F 1878; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This guide covers the evaluation and selection of escort vessels that are to be used to escort ships transiting confined waters. The purpose of the escort vessel is to limit the uncontrolled movement of a ship disabled by loss of propulsion or steering to within the navigational constraints of the waterway. The various factors addressed in this guide also can be integrated into a plan for escorting a given ship in a given waterway. The selection of equipment also is addressed in this guide.

1.2 This guide can be used in performance-based analyses to evaluate:
1.2.1 the control requirement of a disabled ship,
1.2.2 the performance capabilities of escort vessels,
1.2.3 the navigational limits and fixed obstacles of a waterway,
1.2.4 the ambient conditions (wind and sea) that will impact the escort response, and
1.2.5 the maneuvering characteristics of combined disabled ship/escort vessel(s).

1.3 This guide outlines how these various factors can be integrated to form an escort plan for a specific ship or a specific waterway. It also outlines training programs and the selection of equipment for escort-related activities.

1.4 A flowchart of the overall process for developing and implementing an escort plan is shown in Fig. 1. The process begins with the collection of appropriate data, which are analyzed with respect to the performance criteria and in consultation with individuals having local specialized knowledge (such as pilots, waterway authorities, interest groups, or public/private organizations, and so forth). This yields escort vessel performance requirements for various transit speeds and conditions; these are embodied in the ship’s escort plan. When the time comes to prepare for the actual transit, the plan is consulted in conjunction with forecast conditions and desired transit speed to select and dispatch the appropriate escort vessel (or combination of vessels). A pre-escort conference is conducted to ensure that all principal persons (ship master, pilot, and escort vessel masters) have a good understanding of how to make a safe transit and interact in the event of an emergency.

1.5 This guide addresses various aspects of escorting, including several performance criteria and methodologies for analyzing the criteria, as well as training, outfitting, and other escort-related considerations. This guide can be expanded as appropriate to add new criteria, incorporate “lessons learned” as more escorting experience is gained in the industry, or to include alternative methodologies for analyzing the criteria.

1.6 This guide addresses physical control of the disabled ship with the assistance of the escort vessel(s). Other possible functions, such as firefighting, piloting, or navigational redundancy, are outside the scope of this guide. Also, this guide was developed for application to oceangoing ships in coastal waterways; it is not suitable for application to barge strings in riverine environments.

2. Referenced Documents
2.1 Code of Federal Regulations Document:
33 CFR Part 168—Escort Vessels for Certain Tankers, Final Rule
2.2 IMO Resolutions:
IMO Resolution A.601(15)—Provision and Display of Maneuvering Information on Board Ships
IMO Resolution A.751(18)—Interim Standards for Ship Maneuverability
2.3 Marine Safety Committee Circulars:
MSC Circular 389/Interim Guidelines for Estimating Maneuvering Performance in Ship Design
MSC Circular 644/Explanatory Notes to the Interim Standards for Ship Maneuverability

3. Terminology
3.1 For purposes of clarity within this guide, the vessel being escorted is referred to as the “ship” or “disabled ship.” The vessel accompanying the ship as its escort is referred to as the “escort vessel.”

3.2 The escorting measures addressed in this guide are based on performance.

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2 Available from the International Maritime Organization, 4 Albert Embankment, London, SE1 7SR U.K.
3.2.1 The term “performance measure” refers to performance capabilities that must be possessed by the escort vessel(s) in controlling the disabled ship within a particular waterway. This requires a holistic analysis of the combined maneuvering dynamics of the escort vessel(s) and ship within the waterway in ambient weather and sea conditions. Performance-based requirements involve extensive preplanning and analyses, but offer greater assurance that the escort vessel(s) actually will be effective. The methodologies and processes presented in this guide can be used in determining the performance envelope of an escort vessel at different transit speeds and under a range of weather and sea conditions.

3.3 The terms “conventional propulsion” and “omni-directional propulsion” refer to propulsion systems of the escort vessel.

3.3.1 Conventional Propulsion System—The propulsive thrust is fixed in a fore/aft direction.

3.3.2 Omni-Directional Propulsion System—The propulsive thrust is steerable in any direction (360°) around the hull. Examples are the azimuthing Z-drive screw propeller system and the vertical axis cycloidal system.

3.4 The terms “direct mode” and “indirect mode” refer to two towing modes for exerting control forces on a disabled ship via towline from the escort vessel.

3.4.1 Direct Mode—The towline force is derived directly from the escort vessel’s propulsion system. In general, the towline orientation is over the bow or over the stern of the escort vessel, and only the propulsive thrust vector parallel to the towline axis is effective on the disabled ship.

3.4.2 Indirect Mode—The towline force is derived from the escort vessel’s hull drag as it is pulled along behind the disabled ship (similar to a drag chute). High-performance escort vessels should have sufficient stability so that they can turn approximately sideways to the towline without capsizing.
3.6.9 maneuvering coefficients, \( n \)—a set of numerical coefficients the are used in polynomial representations of the forces acting on a ship in terms of the instantaneous state of the ship.

3.6.10 oppose maneuver, \( n \)—an escort vessel maneuver in which the assisting escort vessel(s) apply maximum steering force to a disabled ship to turn the ship against its rudder. In this maneuver, the objective is to return the ship to its original heading by opposing the rudder forces.

3.6.11 propulsion failure, \( n \)—the ship is unable to propel or actively stop itself.

3.6.12 response times, \( n \)—the sequence of time delays following a disabling failure on a transiting ship before the escort vessel(s) can apply corrective forces.

3.6.13 rescue tow, \( n \)—a maneuver in which the escort vessel makes up lines and pulls the disabled ship; undertaken after all forward way has come off the disabled ship.

3.6.14 retard maneuver, \( n \)—an escort vessel maneuver in which the assisting escort vessel(s) apply maximum braking force to a disabled ship. In this maneuver, the objective is to take speed off the ship as quickly as possible by pulling astern. The control of a ship’s heading is not an objective. Also referred to as arrest.

3.6.15 rudder failure, \( n \)—the ship’s rudder is locked at some angle or it is swinging uncontrollably.

3.6.16 ship track/course, \( n \)—the path covered by the ship’s center of gravity during a voyage, a waterway transit, or a maneuver.

3.6.17 tactical diameter, \( n \)—the distance, perpendicular to the original course direction, between the ship’s center of gravity at the start and at the end of a 180° heading change.

3.6.18 zigzag maneuver, \( n \)—a test used to measure the effectiveness of the rudder to initiate and check course changes. The maneuver is described in MSC Circular 644, Section 2.2.

3.7 Evaluation and Selection Variables:

3.7.1 transit speeds, \( n \)—the speed of the escorted ship measured through the water. The transit speed takes into account tidal and wind-driven currents. Transit speed is not over ground (SOG) as measured by Global Positioning System (GPS), Loran, or radar.

3.7.2 bollard pull, \( n \)—the maximum sustainable force that the escort vessel is able to develop while pulling on a towline attached to a stationary object. The forward and astern bollard pull are individually specified.

3.7.3 dynamic pull (at a particular speed), \( n \)—the maximum sustainable force that the escort vessel is able to develop while moving through the water at a particular speed.

3.7.4 transfer, \( n \)—the distance perpendicular to the original track that a ship’s center of gravity travels in a 90° change in heading.

3.7.5 advance, \( n \)—the distance parallel to the original track that a ship’s center of gravity travels in a 90° change of heading.

3.7.6 performance limits, \( n \)—limits of performance measures such that under all circumstances, the use of vessels, equipment, or crew shall not place the life and safety of
individuals in jeopardy. No applicable federal or state regulations should be exceeded in determining escort vessel performance capabilities and limits.

4. Significance and Use

4.1 This guide presents some methodologies to predict the forces required to bring a disabled ship under control within the available limits of the waterway, taking into account local influences of wind and sea conditions. Presented are methodologies to determine the control forces that an escort vessel can reasonably be expected to impose on a disabled ship, taking into account the design of the ship, transit speed, winds, currents, and sea conditions. In some instances, this guide presents formulae that can be used directly; in other instances, in which the interaction of various factors is more complicated, it presents analytic processes that can be used in developing computer simulations.

4.2 Unlike the more traditional work of berthing assistance in sheltered harbors or pulling a “dead ship” on the end of a long towline, the escorting mission assumes that the disabled ship will be at transit speed at the time of failure, and that it could be in exposed waters subject to wind, current, and sea conditions.

4.3 The navigational constraints of the channel or waterway might restrict the available maneuvering area within which the disabled ship must be brought under control before it runs aground or collides with fixed objects in the waterway (see allision).

4.4 The escort mission requires escort vessel(s) that are capable of responding in timely fashion and that can safely apply substantial control forces to the disabled ship. This entails evaluation of the escort vessel’s horsepower, steering and retarding forces at various speeds, maneuverability, stability, and outfitting (towing gear, fendering, and so forth). This guide can be used in developing escort plans for selecting suitable escort vessel(s) for specific ships in specific waterways.

4.5 The methodologies and processes outlined in this guide are for performance-based analyses of escort scenarios. This means that the acceptability of a vessel (or combination of vessels) for escorting is based upon the ability to control the disabled ship in accordance with specified performance criteria. This guide addresses four selected performance measures:

- **Towing**—the ability to tow the disabled ship under specified parameters,
- **Stopping**—the ability to stop the disabled ship within specified parameters,
- **Turning**—the ability to turn the disabled ship within specified parameters, and
- **Holding steady**—the ability to hold the disabled ship on a steady course under specified parameters.

4.6 The “specified parameters” are additional details that must be factored into the performance analysis. These parameters might be specified by a regulatory agency imposing the escort requirement, by a study group evaluating the feasibility of escorting in a particular waterway, or by the ship or escort vessel operators themselves to define the performance envelope of their vessels. Some examples of these parameters are:

- **4.6.1 A ship transit speed (at the moment of failure);**
- **4.6.2 The failure scenario (rudder failure alone, or simultaneous rudder propulsion failure, degree of failure, and so forth);**
- **4.6.3 Navigational constraint within which the disabled ship must be brought under control (such as allowable advance and transfer, cross-track error, and so forth);**
- **4.6.4 Wind, current, and sea conditions; and**
- **4.6.5 Time delays, failure recognition, decision making, escort vessel notification, escort vessel positioning, achieving full power, and so forth.**

4.7 The anticipated users of this guide are:

- **4.7.1 Ship owners/operators who are required to select escort vessel(s) that meet the performance measures addressed by this guide.**
- **4.7.2 Escort vessel designers/operators who need to evaluate the performance capabilities of their vessels with respect to the measures addressed by this guide.**
- **4.7.3 Regulatory agencies that have imposed the performance measures in this guide in a particular waterway to develop suitable escort vessel matrices for various sized ships in the waterway.**
- **4.7.4 Enforcement agencies can use this guide to confirm/verify compliance with the performance measures (that is, that suitable escort vessel(s) are being selected).**
- **4.7.5 Study groups can use this guide to explore the feasibility and effectiveness of escorting as a means of mitigating risk on a particular waterway.**

4.8 This guide does not address the use of escort vessels with barge fleets or barge tows. However, some sections of this guide would be useful if an evaluation of escort vessels with barge shipments were undertaken. Paragraphs 5.4 and 5.5, and all of Section 6 would apply in this type of analysis.

4.9 The methodologies and processes presented in this guide will yield valid solutions to the performance measures. This means that the selected escort vessel(s) can reasonably be expected to control the disabled ship within the specified parameters. However, users are reminded that other circumstances surrounding the disabling incident may still preclude the escorts from safely responding (such as fire).

4.10 The methodologies in this guide are not necessarily the only ones that can be used to find solutions for the performance measures. There may be other analytic approaches that also will yield valid results. It is hoped that as these alternative methods are developed, they will be incorporated into this guide.

5. Data Requirements for Analysis

5.1 This section describes the data required for an escort vessel evaluation and selection analysis. This analysis is part of the development of an escort plan. The data recommended for inclusion in an escort plan document are presented in Section 8.

5.2 The data required for this analysis must be either an accurate evaluation of ship and escort vessel characteristics or must be based on conservative assumptions regarding those characteristics.

5.3 Ship Data:

- **5.3.1 It is recommended that, as a minimum, the ship information contained on the IMO A.601(15) defined pilot card**
and wheelhouse poster be collected for use in developing and verifying an escort vessel analysis. Examples of the pilot card and wheelhouse poster are shown in Figs. 2-5. The completed forms can be made part of an escort plan.

5.3.2 In addition, the following ship-specific characteristics can be used in the development of an escort plan and can be used in the validation of ship-maneuvering simulation computer models:

5.3.2.1 Unpropelled advance and transfer distances starting from an engine stop order with rudder amidships at the proposed transit speed until a speed of 1 knot is achieved in calm conditions at level trim in deep water.

5.3.2.2 Crash stop (full engine astern) advance and transfer distances at a speed of 1 knot with port and starboard locked rudder starting from the proposed transit speed in calm conditions at level trim in deep water.

5.3.2.3 Dead ship tow behavior and tow force requirements for a range of wind speeds characteristic of the escort area, including associated wave heights and the effects of vessel trim on towing behavior.

5.3.2.4 Data from full-scale ship-escort vessel trials, if conducted.

5.4 Escort Vessel Data:

5.4.1 It is recommended that, as a minimum, the escort vessel information shown in Fig. 6 be obtained.

5.4.2 In addition, the additional information shown in Fig. 7 can be used in the development of an escort plan.

---

**Ship’s name: __________________________**  **Date: ________________**

**Call sign: ___________**  **Deadweight: ________ tonnes**  **Year built: ___________**

**Draught aft: _________m/_______ft/_______in.**  **Forward: _________m/_______ft/_______in.**  **Displacement: ________tonnes**

---

**SHIP’S PARTICULARS**

**Length overall: _________m.**  **Anchor chain: Port: _______shackles, Starboard: _______shackles.**

**Breadth: _________m**  **Stern: _______shackles**

**Bulbous bow: Yes/No**

(1 shackle = _______m/_______fathoms)

---

**Type of engine: _______________**

<table>
<thead>
<tr>
<th>Manoeuvring engine order</th>
<th>Rpm/pitch</th>
<th>Speed (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full ahead</td>
<td></td>
<td>Loaded</td>
</tr>
<tr>
<td>Half ahead</td>
<td></td>
<td>Ballast</td>
</tr>
<tr>
<td>Slow ahead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead slow ahead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead slow astern</td>
<td></td>
<td>Time limit astern: _______min</td>
</tr>
<tr>
<td>Slow astern</td>
<td></td>
<td>Full ahead to full astern: _______s</td>
</tr>
<tr>
<td>Half astern</td>
<td></td>
<td>Max. no. of consec. starts: _______</td>
</tr>
<tr>
<td>Full astern</td>
<td></td>
<td>Minimum RPM: _______ knots</td>
</tr>
</tbody>
</table>

| Astern power: _______% ahead |

---

**FIG. 2 Pilot Card**
5.4.3 Alternatively, data from scale model testing or instrumented full-scale trials can be used in the development of an escort plan.

5.5 Waterway Data:

5.5.1 Transit Routes and Escort Zones—Transit route(s) through the escort area must be identified. For routes that pass through distinctly different regions, it may be beneficial to divide the escort area into separate zones based on the environment and the severity of the constraints. This procedure will separate a zone with severe constraints from one that is less restrictive. Different escort vessels can be used in the different zones to satisfy the requirements of this guide.

5.5.2 Navigational Constraints—The geography of the escort area should be evaluated to determine its navigational limits. It is within these constraints that a disabled ship must be stopped or controlled if a grounding is to be prevented. Such limits might be prescribed by a minimum under-keel clearance, a particular depth contour, or a safety distance from a point hazard.

5.5.3 Environmental Conditions—The climatology of the escort area, including wind speeds, wind directions, wave heights, wave periods, wave directions, current speeds, and current directions should be assembled. If there are significant seasonal variations in the climatological conditions and if seasonally varying escort plans are to be prepared, then the climatological data for each season should be assembled.

5.5.4 Particular Hazards—A list of points of particular hazard along the transit route should be compiled.

6. Determination of Escort Vessel Capability

6.1 Two different approaches to escort vessel performance measures are presented. Paragraph 6.2 discusses selected performance measures. Paragraph 6.3 discusses operational performance measures. Operational performance measures differ from selected performance measures in both definition and methodology for determination of adequacy.

6.2 Selected Performance Measures:

6.2.1 Selected performance measures can be thought of as the ship demand for escort vessel capability. These measures can be chosen by regulatory bodies at either the state or national level, or they can be chosen by vessel operators as a means of setting minimum performance standards for their own evaluation and selection of escort vessel(s). These measures can be specified so as to be waterway and weather independent. They would not require consideration of such operational issues as time delays for the application of escort vessel force and procedures for applying those forces.
FIG. 3 Wheelhouse Poster

**Ship's name:__________, Call sign:__________, Gross tonnage:__________, Net tonnage:__________**

Max. displacement ________ tonnes, and Deadweight ________ tonnes, and Block coefficient ________ at summer full load draught.

---

**STEERING PARTICULARS**

<table>
<thead>
<tr>
<th>Type of rudder</th>
<th>Maximum rudder angle</th>
<th>Time hand-over to hand-over</th>
</tr>
</thead>
<tbody>
<tr>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

| Time hand-over to hand-over with one power unit | ________ | ________ |
| With two power units | ________ | ________ |

Minimum speed to maintain course propeller stopped ________ knots

Rudder angle for neutral effect ________

---

**ANCHOR CHAIN**

<table>
<thead>
<tr>
<th>No. of shackles</th>
<th>Max. rate of heaving (mm/shackle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port</td>
<td>________</td>
</tr>
<tr>
<td>Starboard</td>
<td>________</td>
</tr>
<tr>
<td>Stern</td>
<td>________</td>
</tr>
</tbody>
</table>

(1 shackle = ________ m/________ fathoms)

---

**PROPULSION PARTICULARS**

<table>
<thead>
<tr>
<th>Type of engine</th>
<th>750 kW (750 HP)</th>
<th>Type of propeller</th>
</tr>
</thead>
<tbody>
<tr>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

**Engine order**

<table>
<thead>
<tr>
<th>Speed (kn)</th>
<th>Loaded</th>
<th>Ballast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sea speed</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Full ahead</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Half ahead</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Slow ahead</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

**Dead slow ahead**

**Dead slow astern**

Critical revolutions ________ rpm

Minimum rpm ________ knots

**Time limit astern** ________ min

**Time limit at min. revs** ________ min

**Emergency full astern to full astern** ________ s

**Stop to full astern** ________ s

**Slow astern**

**Hall astern**

Aster power ________ s ahead

Max. no. of consecutive starts ________

---

**THRUSTER EFFECT at trial conditions**

<table>
<thead>
<tr>
<th>Thruster</th>
<th>kW (HP)</th>
<th>Time delay for full thrust</th>
<th>Turning rate at zero speed</th>
<th>Time delay to reverse full thrust</th>
<th>Not effective above speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bow</td>
<td>________</td>
<td>________</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Stern</td>
<td>________</td>
<td>________</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Combined</td>
<td>________</td>
<td>________</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

---

**DRAUGHT INCREASE (LOADED)**

<table>
<thead>
<tr>
<th>Under keel clearance</th>
<th>Max. bow yaw (°) estimated (°)</th>
<th>Heel angle (°)</th>
<th>Draft increase (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>4</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>8</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>12</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>16</td>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

---

[Image of the page with the text and tables]
FIG. 4 Turning Circles at Maximum Rudder Angle

LOADED
Water depth/draught ratio = 1.2

BALLAST
1 cable = 0.1 nautical mile

EMERGENCY MANOEUVRES

FULL SEA AHEAD
Comparison of turning (max. rudder) and full astern stopping ability (rudder amidships)

STOPPING CHARACTERISTICS

EMERGENCY MANOEUVRES

FULL SEA AHEAD
Comparison of turning (max. rudder) and full astern stopping ability (rudder amidships)
Note 1—Performance may differ from this record as a result of environmental, hull, and loading conditions.

FIG. 5 Man Overboard Rescue Maneuver
6.2.2 Example performance measures are presented in Appendix X1.

6.3 Operational Performance Measures:

6.3.1 Operational performance measures are ship, waterway, and season specific. An example of this type of performance measure is contained in 33 CFR 168.50 Part (a). It reads, in part: "...at all times during the escort transit each tanker to which this part applies: ...(2) Must have the escort vessels positioned relative to the tanker such that timely response to a propulsion or steering failure can be effected. (3) Must not exceed a speed beyond which the escort vessels can reasonably be expected to safely bring the tanker under control within the navigational limits of the waterway, taking into consideration ambient sea and weather conditions, surrounding vessel traffic, hazards, and other factors that may reduce the available sea room." An operational analysis needs to consider transit speed, time delays, sea and weather conditions, navigational constraints, failure modes, type of assistance used, ship fitting, and other factors.

6.3.2 The adequacy of the escort under this section can be demonstrated through computer simulations, model-scale or full-scale trials, or a combination of both.

6.3.3 Failure Modes—Failure modes for an operational analysis are to be defined. Possible failure modes include propulsion failure, steering failure, or steering failure without the use of ship propulsion. The escort requirements differ significantly, depending on the failure scenario.

6.3.4 Time Delays—Time delays for an operational analysis are to be defined. Actual time delays can vary significantly as a result of differences in human performance, weather conditions, nature of casualty, ship speed, escort vessel type, escort position, escort mode, emergency assist procedures, and equipment. The time delay chain of events should include each of the following, if applicable.

6.3.4.1 Time delay for failure recognition aboard the transiting ship (consideration can be given to on-board failure alarm systems),
6.3.4.2 Time delay to consider options and cures and notify escort vessel(s).
6.3.4.3 Time required to maneuver escort vessel(s) from its escort position to the ship.
6.3.4.4 Time required to connect any lines, and
6.3.4.5 Time required to stream lines and develop tension.
6.3.5 The possibility that an emergency assist might be required under adverse conditions, such as storms, darkness, times of poor visibility, conditions with ice on the decks, or difficult communications caused by winds and darkness, is to be considered.
6.3.6 Estimates should be based on experience, full-scale trials, commentary from experienced masters, and other reliable available data.
6.3.7 Type of Assistance:
6.3.7.1 An escort vessel must be capable of providing assistance in towing, stopping, and steering. The way in which this assistance is provided will depend on the nature of the ship’s casualty, its speed, navigational constraints, escort vessel type, escort position, and escort mode (whether tethered or untethered).
6.3.7.2 The towline forces for steering and braking assist can be substantially higher than the loads that the bitts and chocks of many existing ships have been designed to accommodate. The braking and steering assist forces above the safe limits of the ship’s fittings should not be considered in an operational analysis.
6.3.7.3 The capability limits of escort vessel fittings should be evaluated. Assist forces above the safe limits of the escort vessel fittings should not be considered in an operational analysis.
6.3.7.4 The use of the disabled ship’s astern thrust and the deployment of its anchors to complement the action of the escort vessel(s) or other actions should be considered.
6.3.8 Navigational Constraints:
6.3.8.1 A quantitative definition of the navigational constraints for each escort zone in terms of an allowable reach and an allowable transfer must be determined. The analysis is to include distances to point constraints such as bridges, rocks, and islands, as well as to bottom contours. In evaluating the navigational constraint, consideration can be made between grounding on hard bottom, which may potentially open the hull, and on soft bottom, such as mud, which may not.

6.3.8.2 It is not intended that the escort analysis or escort plan define the transit route that ships must take in a particular waterway. It is recognized that tracklines chosen during an actual transit may differ from those used in the preparation of the escort plan. However, the escort plan should be based on the average or most likely route that the ship will take in the waterway. Thus, allowable reach and transfer distances can be based on the average or most likely transit route.

6.3.8.3 The offtrack distances from a disabling failure scenario, including the effects of escort vessel assistance, are to be compared with these allowable distances to determine the adequacy of escort vessel selection. The offtrack distances can be obtained from full-scale trials, model-scale testing, or computer simulations.

![FIG. 7 Escort Vessel Additional Data Form (continued)](image)

<table>
<thead>
<tr>
<th>Rudder Type: (Flat Plate, Trailing Edge Wedge, NACA, High Lift, other)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Rudder Angle</td>
</tr>
<tr>
<td>Chord</td>
</tr>
<tr>
<td>Span</td>
</tr>
<tr>
<td>Aspect Ratio</td>
</tr>
<tr>
<td>Rudder Area</td>
</tr>
</tbody>
</table>

**ENGINES:**

<table>
<thead>
<tr>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer and Type</td>
</tr>
<tr>
<td>Maximum RPM</td>
</tr>
<tr>
<td>Rated RPM</td>
</tr>
<tr>
<td>BHP at Rated RPM</td>
</tr>
<tr>
<td>Gear Ratio</td>
</tr>
<tr>
<td>Gear Efficiency</td>
</tr>
<tr>
<td>Shaft Efficiency</td>
</tr>
</tbody>
</table>

**PROPPELLERS**

| Type: open wheel, nozzle, steerable nozzle, azimuthing, cycloidal, other |
| Four quadrant Kt vs Beta curves                                    |
| Propeller Interaction Effects                                     |
| Longitudinal Coordinate of Center of Thrust for Propellers        |
| Transverse Coordinate of Center of Thrust for Propellers          |
| Vertical Coordinate of Center of Thrust for Propellers            |

**FENDERING**

<table>
<thead>
<tr>
<th>Description (Type, materials, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (Vertical Extent at Bow, Length along side, Depth from hull)</td>
</tr>
<tr>
<td>Locations (Bow, midship, stern, etc.)</td>
</tr>
</tbody>
</table>
6.3.8.4 There are several methods of determining the numerical values of the available reach and transfer distances. The simplest is to choose the absolute minimums as used from a trackline chosen for each ship’s purposes. Using this definition, the reach constraint would be the shortest straight-ahead distance from a turn in the transit route to the constraint directly ahead. The minimum transfer distance would be the shortest perpendicular distance to constraints on either side. However, if this approach is adopted, the escort requirement would be based on a single-point exposure to the worst case hazard, which may be too restrictive in relation to the entire transit route.

6.3.8.5 An alternative approach is to define the reach and transfer constraints as a statistical measure of the exposure of the vessel to potential grounding/allision situations. The statistical measure could be the average distance ahead and abeam measured throughout the entire transit in the escort zone of interest. Percentile measures of reach and transfer distances can also be determined. For example, the 95th or 98th percentile levels can be used to define the navigational constraint. The procedure for the calculation of statistically defined constraints begins by measuring the reach and transfer distances from the normal ship track to a constraint. To do this, the transit is divided into evenly spaced segments, and the ahead and abeam distances measured. A histogram of the measurements showing the frequency distribution of reach and transfer is then constructed (Fig. 8). Cumulative frequency distributions are developed and used to determine the percentile reach and transfer for any particular transit. An example calculation is shown in Figs. 9 and 10.

6.3.8.6 Other reasonable methods of determining available reach and transfer distances may be developed.

6.3.9 Environmental Conditions—The behavior of a disabled ship and the capability of an escort system are influenced by the environmental conditions. The environmental factors to be considered include wind speeds, direction and duration, wave heights, periods and directions, current velocities, and direction. Seasonal variations in climatological conditions should be considered in escort operations analysis and escort vessel selection.

6.4 Stability of Escort Vessels:

6.4.1 Some modes of escorting may result in an escort vessel being subjected to forces, both static and dynamic, that cause heeling moments in excess of those for which the escort vessel was originally designed.

6.4.2 Conventional stability analysis techniques consider the effects of heeling moments only in a static condition. The impact of vessel speed and the resulting hydrodynamic forces acting on the vessel are not considered.

6.4.3 Escort vessels with omni-directional propulsion systems deliberately can be placed abeam to the direction of the tow line to achieve high retarding forces. Such attitudes can result in high heeling angles at higher speeds and, thus, a potentially sudden incidence of deck edge submergence.
6.4.4 The stability analysis of escort vessels must consider all potential attitudes of the escort vessel to the direction of line pull, the maximum line pull, and the resultant combination of heel and trim on the escort vessel.

6.4.5 For all escort vessels, a limiting heel angle must be established. This limit might be the geometrical submergence of the main deck, including the loss of freeboard as a result of waves.

6.4.6 The stability analysis must include the effects of fenders, skegs, nozzles, rudders, and any other appendages on both the reserve buoyancy and the lateral resistance of the escort vessel.

6.4.7 The stability analysis must include the contribution to heel and trim of the propulsion system in conjunction with maximum line forces.

6.4.8 The stability analysis must include an evaluation of the reaction of the escort vessel to an instantaneous release of the line forces and the propulsive forces.

6.5 Procedures for Determination of Escort Vessel Capabilities:

6.5.1 Full-Scale Trials:
6.5.1.1 Full-scale ship-escort vessel trials, wherever they can be properly designed and safely executed, may be used to verify the adequacy of escort vessel(s). These trials should be carefully planned in conjunction with ship owners and escort vessel operators to ensure proper evaluation of escort vessel(s).

The differences between the environmental conditions prevailing at the time of the test and the postulated environmental conditions during the actual transit should be accounted for in the analysis.

6.5.1.2 Full-scale ship-escort vessel makeup trials can provide examples of the time taken by an escort vessel to approach a ship and begin to render effective assistance. However, the trials may take place in conditions different from emergency conditions and when the crew is fully prepared for the test. Thus, time delays obtained in these tests will, in most cases, underestimate the time required in a true emergency.

6.5.1.3 The ship’s position during the course of the trials is to be continuously recorded. Observers should be stationed on the vessels to monitor the precise sequence of events aboard the ship and the actions taken by the escort vessel(s). The water depth, the ship’s loaded condition, the load condition of the escort vessel, and the environmental conditions prevailing at the time of the trials are to be noted.

6.5.1.4 At no point in the course of the trials should the safety of the vessels and their crew be compromised.

6.5.1.5 At the conclusion of the trials, the results are to be analyzed and the ship tracks plotted. Corrections for any currents, wind loads, ship and escort vessel operating condition, and the GPS antenna location on the ship are to be incorporated, if applicable.

6.5.2 Ship Model for Computer Simulation:
6.5.2.1 As an alternative to full-scale trials, a validated ship-maneuvering simulation program can be used to verify the adequacy of escort vessel(s).

6.5.2.2 The coefficients of the underlying mathematical model of ship maneuvering may be obtained from an appropriate database established by properly conducted physical model tests. The coefficient set shall be suitable for the type of ship and the waterway bathymetry being modeled. Restricted water effects, such as bank suction and shallow water effects on maneuvering, shall be considered. Effects of ship-ship interaction on maneuvering shall be considered where appropriate.

6.5.3 Escort Vessel Model for Computer Simulation:

6.5.3.1 The performance of an escort vessel in an emergency maneuver depends on its ability to apply corrective forces to the disabled ship either through a line or through direct contact with the ship’s hull. The forces may be applied while the disabled ship is still moving at speeds close to its transit speed, except where sea room is available to allow the disabled ship to slow without escort vessel intervention. Three distinct assist modes are to be evaluated. They are: stopping (also called retarding or arresting), steering, and towing. The assist forces in these modes should be properly evaluated and applied to the ship model as external forces.

6.5.3.2 Conventionally propelled escort vessels apply braking force by backing down on a head line while being dragged through the water by the disabled ship. The braking capability and clutch-in speed of a conventional escort vessel can be calculated using fourth quadrant open water propeller curves for the installed propellers, including the hull-propeller interaction effects, and the drag of the hull. For conventionally propelled escort vessels, the braking force may be assumed to be constant up to the clutch-in speed and equal to that measured in reverse bollard pull trials.

6.5.3.3 The braking force of a vertical axis cycloidal escort vessel (in direct and indirect modes) and the braking force of an azimuthing propelled escort vessel (in reverse, transverse, or indirect modes) can be calculated from open water propeller curves for the installed propellers, including the hull-propeller and propeller-propeller interaction effects, and the lift and drag of the hull at its equilibrium attitude to the flow.

6.5.3.4 Alternatively, the braking force as a function of advance speed can be determined from scale-model testing or instrumented full-scale trials.

6.5.3.5 The emergency assist steering capability of the escort vessels can be quantified by a pair of speed-dependent vector force functions, a maximum steering force together with an associated pushing or braking force. The hydrodynamics of the underwater hull with any skegs, rudders, and appendages, the propeller characteristics and stability, including freeboard and metacentric height, should be considered in the evaluation of these vector force functions. The assumed position of the escort vessel at the bow or stern, or when pushing on the side or transom, or when pulling on a line, is to be properly modeled. When the escort vessel is pushing on the transom or

FIG. 10 Example Statistical Transfer Distances
the side of the disabled ship or pulling on a headline, the steering force is accompanied by a longitudinal force which affects the speed of the disabled ship. Likewise, when steering by pulling on a line from the stern of the disabled ship, the steering force is accompanied by a braking force which can affect the speed of the ship.

6.5.3.6 For all escort vessel types, a heel angle limit should be established. This limit can be the geometrical submergence of the main deck edge including the loss of freeboard as a result of waves. Even though it may be possible to submerge a portion of the main deck and produce somewhat larger steering forces, the stability of the escort vessel decreases rapidly.

6.5.3.7 The emergency assist steering capability of the escort vessel can be calculated by solving the equilibrium free body problems for a hull in a free stream. The solution corresponds to a quasi-steady state condition in which the horizontal-plane forces and moments are in balance. The dynamic fluctuations in the forcing functions can be assumed to be negligible with respect to the time rate of change of ship momentum, and small with respect to the average force capability of the escort vessel. The analysis should include the hydrodynamic forces on the escort vessel hull, skeg, and other appendages and fenders; the lift and drag forces acting on the rudders (if present); and the thrust of the propellers. The analysis should include flow modifications, such as the flow straightening and wake effects of the hull on the flow entering the propellers, and modifications to the direction and magnitude of the velocity field acting on the rudders (if present) as a result of the propeller slipstream. In addition to the hydrodynamic forces on the underwater hull, the equilibrium is affected by all lines and escort vessel-ship contact. The components of a complete quasi-steady state analysis are summarized in Appendix X2. Effects of escort vessel motions on freeboard can be ignored. These are time-dependent dynamic processes and can be assumed not to affect significantly the quasi-steady state solution.

6.5.3.8 Alternatively, the emergency assist steering force as a function of advance speed can be determined from scale-model testing or instrumented full-scale trials.

6.5.3.9 Towing capability can be determined by the thrust and torque characteristics of the propeller and the resistance of the escort vessel, towed vessel, and towline at speed. The calculation should use an accurate model of the escort vessel’s propulsion system. The solution of thrust, torque, RPM, and required power should be checked for propeller cavitation, RPM limitations, and engine capacity. The towing capability predicted in calm water should be modified for sea conditions by reducing the RPM of the engines and adding steady wave forces and wind loads to the escort vessel hull.

6.5.3.10 Capability Reductions Because of Vessel Condition—Towing performance is reduced as the engines, shafting, and propellers deviate from design specifications. Accountability should be made for significant changes in capability caused by any change in escort vessel condition. The performance of a selected escort vessel can change as a result of the degradation of equipment or stability characteristics over time. The capability of the selected escort vessel(s) should be reassessed periodically to ensure the performance is adequate to meet the needs of the escort plan.

6.6 Escort Vessel Equipment:

6.6.1 The fittings and equipment installed in an escort vessel must be capable of, and suitable for, the safe transmission of forces and loads between the escort vessel and the designated ship. Both the equipment and the manner in which it is connected to the structure of the escort vessel must be designed in recognition of the maximum loads anticipated during emergency maneuvers.

6.6.2 Towline Winch—Winches designed for installation on board escort vessels shall be designed and constructed in accordance with the following specifications:

6.6.2.1 The winch foundation, drum, and ancillary structures shall be designed to accept the maximum anticipated dynamic and static loads with appropriate factors of safety.

6.6.2.2 Winch performance shall be commensurate with the operator’s requirements for safe operations. Performance criteria of light line speed, static line pull, and brake capacity of the winch should be considered when evaluating the escort vessel’s suitability. Other tow winch features that should be considered are a fail-safe and properly located abort mechanism, load tension devices, and a method to spool the towline to prevent burying under severe tension.

6.6.3 Towlines:

6.6.3.1 The towline between the escort vessel and ship is critical to any successful escort maneuver, but should be designed as the weak link in the system. The towline should fail before any mechanical or structural component on the escort vessel. If the strength of the towing connection on a designated ship is unknown or suspect, the escort vessel operator may consider operational restrictions that would reduce the potential for high line loads.

6.6.3.2 Towlines for escort service should be sized to the mission and capabilities of the escort vessel, with consideration of the appropriate safety factor of the type of line used.

6.6.3.3 Towlines for escort duty must be routinely inspected for proper condition.

6.6.4 Towline Connectors—Instead of a line winch and towline stored aboard and controlled by the escort vessel, the connection between the escort vessel and ship may be made by using a towline stored aboard the designated ship. In this case, the escort vessel must be equipped with a device capable of the following:

6.6.4.1 Rapidly and safely securing the line to the escort vessel,

6.6.4.2 Rapidly and safely disconnecting the line from the escort vessel, and

6.6.4.3 Sustaining the highest anticipated loads experienced during the escort maneuvers.

6.6.5 Ground Tackle—Escort vessels should be equipped with ground tackle (anchors, cables, and so forth) in compliance with classification society requirements for ocean service.

6.6.6 Fendering:

6.6.6.1 Escort vessels shall be fully fendered to preclude damage in the event of contact between the escort vessel and the designated ship.
6.6.6.2 Fender type and geometry shall be arranged to provide a resilient contact zone between the escort vessel and ship, such that when the maximum static bollard pull of the escort vessel is applied, the structural limits of the ship’s side or stern are not exceeded, and the fender system is not stressed beyond its design limits.

6.6.7 A line-throwing apparatus is required to facilitate rapid connection between the escort vessel and the ship.

7. Methodology for Escort Vessel Selection

7.1 The methodologies presented in this section provide the user with three alternatives for analyzing an escort situation and can be used as guidance in the selection of an escort vessel. The different approaches are: (1) a ship-specific analysis using computer simulation of specific escort vessel(s) in a matrix of operating conditions; (2) a parametric study of the trends in the results of escort vessel-assisted maneuvers using a number of ships, escort vessel(s), and operating conditions; and (3) a demand versus capability study.

7.2 Other methodologies may be developed for escort vessel selection, but must be validated with literature citations, scale-model testing, or full-scale testing.

7.3 Simulation Matrices:

7.3.1 The use of a matrix of scenarios to identify escort requirements is based on an analysis of individual or representative ships matched with specific escort vessel(s). This method requires using ship-specific and escort vessel-specific information.

7.3.2 A matrix of simulation cases is to be defined so that acceptable escort solutions can be identified for each escort area and transit condition. The matrix should include appropriate combinations covering all relevant geographic regions, climatic conditions, navigational conditions, operating speeds, failure modes, escort deployments, time delays, and types of assistance.

7.3.3 A computer simulation of the escort vessel acting on the disabled ship should be carried out for each combination in the matrix. The resulting ship trackline should be plotted and then compared with the navigational constraints of the waterway. Based on this process, acceptable escorts are identified for all applicable geographic regions, climatic conditions, navigational conditions, and transit speeds.

7.3.4 Computer simulation of disabled ship maneuvers with escort vessel assist requires a validated computer model. This can be accomplished using the ship and escort vessel information discussed in 5.1, 5.2, and Section 6. Additional validation can come from full-scale trials.

7.4 Parametric Studies:

7.4.1 A parametric study is an extension of the matrix of simulation cases presented in 7.3. However, unlike the matrix of cases described in 7.3, which evaluated specific climatic conditions and transit speeds, this approach uses a matrix of scenarios based on parametric variations in climatic conditions, operating speeds, and time delays. Each scenario in the matrix is analyzed using a particular ship and escort vessel.

7.4.2 The results of the parametric study can be presented in a graphical form by plotting a measure representing the outcome of the emergency assist (transfer distance) as a function of any of the underlying parameters, while holding the remaining parameters fixed. For example, a plot of the transfer distance as a function of the initial speed will clearly demonstrate the change in the escort vessel’s ability to control the ship as transit speed changes. Similarly, a plot of the transfer distance as a function of wind speed or current speed will show the change in the ability of the escort vessel to control a disabled ship in different climatic conditions. In this example, comparing the transfer results with the navigational limits of the waterway will enable the selection of a transit speed or an environmentally imposed operational limit.

7.4.3 Computer simulation of disabled ship maneuvers with escort vessel assist requires a validated computer model. This can be accomplished using the ship and escort vessel information discussed in 5.1, 5.2, and Section 6. Additional validation can come from full-scale trials.

7.5 Demand Versus Capability Formulation:

7.5.1 The approach is advantageous when a diverse range of escorted ships and escort vessels are to be considered. It can be used to select a suitable escort system for a given ship at a prescribed displacement and speed, transiting a particular escort area. The ship’s “demand” for assist forces is separated from the “capability” of the escort vessel and must not exceed the demand to have an acceptable escort system.

7.5.2 The demands of the ship requiring escort shall be quantified as a function of the displacement, speed, time delays, and the prevailing environment. The “demand” measures generally take on scalar values of force or distance. They should be specific to the failure mode and the escort area. They are to be independent of escort vessel parameters.

7.5.3 The capabilities of a vessel providing escort should be established as a function of the speed and the prevailing environment. They should be independent of ship parameters. The capability measures must have the same measurement units as the demand.

7.5.4 Once the demands and capabilities are established, they should be clearly tabulated. The governing demand can be taken as the maximum demand across all possible failure modes. An escort vessel or escort vessel combinations with a total capability sufficient to meet or exceed the governing demand qualify as acceptable escorts. Alternative escort choices for any given ship at a prescribed displacement and transit speed in any escort area should then be easily identifiable from the tables.

7.5.5 Because of the simplifying assumptions inherent in a demand versus capability formulation, the demand and capability determination of escort vessel selection should be double-checked. This should be done by demonstrating that the selected escort vessel(s) capabilities meet or exceed the demand of a disabled ship, and that they are capable of rendering timely assistance to the disabled ship and bringing it under control within the navigational limits of the waterway, taking into consideration ambient sea and weather conditions, surrounding vessel traffic, hazards, and other factors that may reduce the available sea room. The validation should be carried out through full-scale trials or computer simulations and should cover the full range of ship, escort vessel, and environmental parameters.
8. Preparation of An Escort Plan

8.1 Components of an Escort Plan—This section provides recommendations for developing an escort plan. The plan may be ship- or ship class-specific. It should provide clear and precise instructions regarding the escorted segment of the voyage. Forms are to be developed and included in the plan for presenting the applicable voyage, ship- and escort vessel-specific information. Flowcharts may be developed for the various activities to be performed.

8.2 Information and Assumptions:

8.2.1 It is recommended that able ship-maneuvering characteristics be compiled in the form of the maneuvering booklet recommended in IMO Resolution A.601(15). MSC/Circular 389 may be consulted for guidance on estimating maneuvering performance. In addition, escort-specific information, including the current condition of the ship with regard to its loading, propulsion and maneuvering equipment, and so forth, should be available in the form of the pilot card recommended in IMO Resolution A. 601(15).

8.2.2 The plan should include all additional information that is useful for understanding the ship’s behavior and how it affects emergency assist requirements. If this information is not available, the escort plan should indicate that it is not available. Data from full-scale ship-escort vessel trials, if available, are to be assembled and included in the escort plan.

8.2.3 Any assumptions used in the selection of the escort vessel(s) should be documented. These include time delays, failure modes, environmental conditions, and emergency assist maneuvers.

8.2.4 Particular Hazards—The escort plan should include a list of points of particular hazard along the escort transit or shall contain a reference to the relevant published compilation of the points of particular hazard, such as the Coast Pilot.

8.2.5 All Coast Guard, VTS, and marine traffic control contacts, radio frequencies, and phone numbers for the escort area should be listed in the escort plan.

8.2.6 The climatology of the escort operating area, including winds, currents, and sea conditions, should be assembled and included in the escort plan. If there are significant seasonal variations in the climatological conditions and if seasonally varying escort plans are to be prepared, then the climatological data for each season should be assembled and included in the escort plan.

8.3 Equipment and Deployment:

8.3.1 A stand-alone diagram or flowchart can be included that describes the equipment involved and the methods employed in making an emergency towline connection (if one is required to be made in accordance with the escort plan).

8.3.2 The plan should include the location and load capacities of the bitts, chocks, and hard points to be used in an emergency assist.

8.4 Escort Selection:

8.4.1 The escort plan should indicate available escort vessel or vessel combinations capable of providing escort.

8.4.2 The plan should specify where to position the escort vessel(s). In this section, consideration should be given to the safety of the escort vessel(s) and to the time it takes for the escort vessel(s) to provide the emergency assistance.

8.4.3 The plan should specify whether the escort vessel(s) will be tethered or not and, if tethered, whether it will be tethered during all or a portion of the transit.

8.4.4 If any portion of the escort transit is untethered, then the plan should define if and how the escort vessel(s) will tether during an emergency.

8.5 Escort Transit Speed:

8.5.1 The speed for a specific transit should be determined in compliance with 33 CFR 168. This speed might depend on the anticipated environmental conditions (winds, currents, and sea conditions) and the capability of the escort vessel(s).

8.5.2 The intended speed for each portion of the transit should be clearly indicated on the escort plan.

8.5.3 The plan should contain a notice that the speeds written are “through the water” speeds and that they differ from speeds “over ground” by the amount of the current.

8.6 The plan should contain documentation of the results of all proposed emergency assist maneuvers. The predicted outcome of the emergency assist maneuvers should be shown on the escort plan at key points along the route.

8.7 Alternatives to Primary Plan—The escort plan should clearly spell out alternative procedures for controlling the disabled ship if the primary plan cannot be executed.

8.8 Pre-Escort Planning and Conference—The plan should contain a procedure and a form (a sample format is given in Table 1) to use when conducting a pre-escort conference. The condition of the environment in which the escort is to take place, including winds, currents, and sea conditions and the consequences for escort vessel selection, should be discussed.

9. Keywords

9.1 disabled ship; escort plan; escort vessel; navigational limit; ship transit
Table 1 Pre-Escort Conference Guide

**Table 1 Pre-Escort Conference Guide**

**Note** 1—Inbound ships: The pre-escort conference (PEC) should be conducted after safely clearing the pilot boarding area and before entering the escort zone. Outbound ships: The PEC should commence before getting underway.

<table>
<thead>
<tr>
<th>USCG Rule</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit: The destination, route, planned speed, other vessel traffic, anticipated weather, tide, sea conditions, and other navigational considerations</td>
<td>Our destination is _______ via _______ (strait); Transit speed will be _______. Anticipated weather/sea conditions are _______. The predicted tide is _______. All vessels monitor VTS for traffic.</td>
</tr>
<tr>
<td>Vessels should report any unusual equipment specifications, extraordinary handling characteristics, or operational deficiencies at this time.</td>
<td></td>
</tr>
<tr>
<td>Escort vessel(s) will be deployed in the following manner.</td>
<td></td>
</tr>
<tr>
<td>Escort vessel(s) will be deployed in the following manner.</td>
<td></td>
</tr>
<tr>
<td>Preparedness: The preparations required on the ship and escort vessel(s), and the methods used in making an emergency towline connection, including stationing of deck crews, preparation of messenger lines, bridles, and other towing gear, and energizing appropriate deck equipment</td>
<td>All vessels will prepare their decks and crews for escort and emergency response for the transit.</td>
</tr>
<tr>
<td>In the event of an emergency, the escort vessel(s) will be deployed as necessary, subject to the circumstances at the time.</td>
<td></td>
</tr>
</tbody>
</table>

**APPENDIXES**

(Nonmandatory Information)

**X1. SELECTED PERFORMANCE MEASURES**

X1.1 Example performance measures in three assist modes are described herein. The demand and capability method described in 7.5 can be used to verify the compliance of an escort with these measures. In this method, the various parameters are first applied to the ship to determine the “demand.” The demand in these examples is some measure of performance, such as towing resistance, stopping ability, rudder force, or turning ability. This measure of performance is a function of the ship, its displacement, dimensions, proportions, propulsion system, and rudder system. The example assist modes are:

**X1.1.1 Ability to Tow the Disabled Ship at a Specified Speed in Calm Conditions and Holding It in a Steady Position Against a Specified Head Wind:**

X1.1.1.1 The ship demand in the first case is equal to the calm water resistance of the ship at the specified towing speed. The resistance of a ship may be estimated by the following:

\[ R = \frac{4\pi}{1000} C_{R} \rho \frac{V^{2/3}}{V^2} \]  

where:

- \( R \) = resistance,
- \( \rho \) = density of the water,
- \( V \) = displaced volume, and
- \( V \) = specified towing speed, in any consistent system of units.

\( C_{R} \) may be taken as 0.65 for a tanker or bulk carrier. Use any consistent set of units.
X1.1.2 The ship demand in the second case is equal to the wind load caused by the specified head wind. The load as a result of a head wind can be calculated as follows (loads are not included): 

$$F_w = K_p A_T V_w^2$$  \hspace{0.5cm} (X1.2) 

where:

- $V_w$ = the specified wind speed and 
- $A_T$ = the equivalent transverse projected area obtained by adding 30% of the projected transverse main hull area to the projected superstructure area. 
- $K_p$ may be taken to be 0.6. Use any consistent set of units. 

X1.1.3 The escort vessel(s) must have sufficient tow rope pull to match or exceed $R$, the calm water towing resistance at the specified speed, and their bollard pull must match or exceed the wind load, $F_w$. The wind drag resistance of the escort vessel is considered negligible and is ignored. 

X1.1.2 Ability to Hold the Ship on a Steady Course Against a Locked Rudder at a Specified Speed:

X1.1.2.1 The ship demand in this case is equal to the lift force generated by the rudder in a specified locked position with the propeller free wheeling at the RPM corresponding to the ambient flow. 

X1.1.2.2 In maneuvering simulation equations, the lift force generated by the rudder is represented by the following:

$$Y_{Rad} = \frac{1}{2} \rho L^2 U_R^2 \delta Y_{br}$$  \hspace{0.5cm} (X1.3) 

where:

- $Y_{Rad}$ = the lateral force, 
- $L$ = the length between perpendiculars, 
- $U_R$ = the assumed flow velocity at the rudder location, 
- $\delta$ = the rudder angle in radians, and 
- $Y_{br}$ = the nondimensional maneuvering coefficient used to represent the lateral rudder force as a function of the rudder angle and should depend on the effective rudder area. 

X1.1.2.3 The escort vessel(s) must be capable of generating counteracting steering forces at the specified speed to match or exceed this demand. The ship can then be held on a steady course, provided the steering force is applied at the transom. 

X1.1.2.4 This solution applies only to a single escort vessel applying steering forces at the transom. If multiple escort vessels are used, the moment arms of the rudder steering force and the counteracting steering forces must be determined and matched. 

X1.1.3 Ability to Turn the Ship 90°, Assuming a Free-Swinging Rudder in Deep Water and an Initial Specified Speed, Within a Specified Reach and Transfer Distance:

X1.1.3.1 When the escort vessel steering force is applied, the ship is assumed to be unpropelled, the rudder is assumed to be ineffective, and the escort vessel assist is to be treated as immediate and without time delay. Deep water is assumed. 

X1.1.3.2 The advance and transfer of the able ship may be obtained from the maneuvering card posted in the wheelhouse. Since the advance and transfer are nearly independent of speed, the wheelhouse information for slow speeds can be used in the evaluation at other speeds. 

X1.1.3.3 The behavior of the disabled ship with escort vessel assistance has to be assessed through ship-maneuvering simulations, model-scale, or full-scale trials. With the requirement to meet both the reach and transfer constraints simultaneously, the effect of the differences in steering modes between escort vessel types should be properly accounted for in the simulations. 

X1.1.4 The selected performance measure “demands” must be matched by the “capabilities” of escort vessel or escort vessel combinations. The ship operator can use these measures to choose any escort vessel combination that has sufficient capability to meet the demand. 

X1.1.5 Alternative validated methodologies for the calculation of the selected performance measures can be used. 

X2. COMPONENTS OF A STEADY-STATE ESCORT VESSEL PERFORMANCE ANALYSIS

X2.1 Lift, drag, and center of pressure of hull. 

X2.2 Lift, drag, and center of pressure of rudders, based on published flat plate and lifting surface coefficients, including effects of aspect ratio and edge effects (for conventional escort vessels). 

X2.3 Lift, drag, and center of pressure of skeg, including effects of aspect ratio. 

X2.4 Modification of flow into rudders resulting from hull shape (for conventional tugs). 

X2.5 Modification of flow into rudders resulting from momentum changes induced by the propellers (for conventional tugs). 

X2.6 Position of rudders with respect to propellers and local rudder angles (for conventional tugs). 

X2.7 Cross-flow effects as a result of tug orientation with respect to the free stream. 

X2.8 Effects of fendering on hydrodynamic performance of the hull. 

X2.9 Propeller performance, including engine, gearbox, and shafting characteristics, command RPM, and propeller geometry. 

X2.10 Effects of twin screw control. 

X2.11 Lift, drag, and center of pressure of propeller nozzles, if present. 

X2.12 Heeling moments caused by contact with ship, bow lines (if rigged), and transverse components of hull, skeg, rudder, nozzle, and propeller forces.
X2.13 Heeling moments caused by tow line tension (for tractor tugs working on a line).

X2.14 Freeboard and GM in the design condition, and the escort condition.

X2.15 Reduction in freeboard as a result of average wave amplitudes.

X2.16 Deck edge submergence.

X2.17 Friction between its fendering and the ship’s hull (for tugs working in contact with the disabled ship’s hull).

X2.18 Forces in lines.

X2.19 Position of tug on ship, either alongside, on the transom, or on a line.

X2.20 Use of additional thrusters.

X2.21 Actual condition of propellers and rudders, that is, effects of wear or damage.

X2.22 Reductions in available power because of vessel condition and maintenance.
Standard Practice for Selection of Wire and Cable Size in AWG or Metric Units

1. Scope

1.1 This practice is intended as a guide to shipbuilders, shipowners, and design agents for use in the selection of conductor size for single conductor or multiple conductor cable sizes either in American Wire Gauge (AWG) or metric designations for commercial ship design and construction.

1.2 The comparison chart of electrical conductor sizes shown in Table 1 presents a combined listing of international standard sizes of Class 2 stranded copper conductors in accordance with AWG (Specification B 8) English units or IEC (IEC 60228) metric units.

1.3 As a precautionary caveat, some conductor sizes listed in Table 1 may exceed minimal size requirements of the U.S. Coast Guard, the American Bureau of Shipping, and IEEE STD 45 for specific applications.

1.4 The values stated for ampacity and dc resistance are presented as maximum values and are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:
B 8 Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
B 193 Test Method for Resistivity of Electrical Conductor Materials

2.2 IEC Standards:
IEC 60092-350 Electrical Installations in Ships—Part 350: Shipboard Power: Cables—General Construction and Test Requirements
IEC 60228 Conductors of Insulated Cables

2.3 IEEE Standard:
IEEE STD 45 Recommended Practice for Electric Installations on Shipboard

TABLE 1 Conversion Table—AWG/Metric Preferred Sizes of Conductors

<table>
<thead>
<tr>
<th>Size Metric, mm²</th>
<th>Size AWG/MCM</th>
<th>Area in Circ Mils (Nominal)</th>
<th>Ampacity A</th>
<th>dc Resistances at 20°C a</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000* c</td>
<td>2 000 000</td>
<td>1155</td>
<td>0.0053</td>
<td>0.0177</td>
</tr>
<tr>
<td>1750*</td>
<td>1 970 000</td>
<td>1145</td>
<td>0.0054</td>
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<td>1500*</td>
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<td>1009</td>
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<td>0.0199</td>
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<td>890</td>
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<tr>
<td>1000*</td>
<td>1 200 000</td>
<td>880</td>
<td>0.0096</td>
<td>0.0286</td>
</tr>
<tr>
<td>800*</td>
<td>1 000 000</td>
<td>780</td>
<td>0.0106</td>
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<tr>
<td>630*</td>
<td>987 000</td>
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</tr>
<tr>
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</tr>
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<td>0.1000</td>
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<tr>
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</tr>
<tr>
<td>125*</td>
<td>167 000</td>
<td>230</td>
<td>0.0752</td>
<td>0.2700</td>
</tr>
<tr>
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<td>138 000</td>
<td>185</td>
<td>0.0979</td>
<td>0.2605</td>
</tr>
<tr>
<td>95*</td>
<td>187 000</td>
<td>265</td>
<td>0.0631</td>
<td>0.2065</td>
</tr>
<tr>
<td>80*</td>
<td>138 000</td>
<td>230</td>
<td>0.0752</td>
<td>0.2700</td>
</tr>
<tr>
<td>70*</td>
<td>106 000</td>
<td>175</td>
<td>0.0979</td>
<td>0.2605</td>
</tr>
<tr>
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<td>140</td>
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<td>144</td>
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</tr>
<tr>
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3. Significance and Use

3.1 The selection criteria is to be applied for uses of (1) new cable and (2) replacement cable.

3.2 For the selection of new cable or the selection of replacement cable, this practice defines the choice criteria for conductor selection for cables in AWG (ASTM) or metric (IEC) sizes.

4. Selection Criteria

4.1 When selecting cable for any application, AWG or metric sizing should be selected according to preferred sizes. The sizes of conductors that have been marked with an asterisk in Table 1 designate preferred sizes per Specification B 8 and IEC 60228. Those sizes not marked are given for reference, and it is recommended that their use be discouraged.

4.2 When selecting cable for any application, AWG or metric sizing should be selected with full consideration of the relationship of type of insulation and ampacity. Direct selection between AWG and metric sizes can be made only after a determination of the equivalence of insulation is made.

4.3 When selecting cable, the conductor size will be determined from analysis of required ampacity, voltage drop considerations, type of cable insulation, and planned installation. Recommended practices for selection and installation of cable systems are detailed in IEEE STD 45 and IEC 60092-350.

4.4 For the selection of cable sizes for new applications, conductor size that satisfies ampacity requirements, voltage drop factors, and the adequacy for application in the available cable space must also be considered.

4.5 For the selection of cable sizes for replacement applications, cable size should be selected in excess of or equal to the replaced cable size. Existing cable space limitations should then be determined to ensure that space for installation of the replacement cable is adequate.

5. Keywords

5.1 AWG conductor sizes; cable selection; conductor comparison; metric conductor sizes

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**TABLE 1** Continued

<table>
<thead>
<tr>
<th>Size Metric, mm²</th>
<th>Size AWG/MCM</th>
<th>Area in Circ Mils (Nominal)</th>
<th>Ampacity A</th>
<th>dc Resistances at 20°C R</th>
<th>Ohms per 1000 ft</th>
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</tr>
</tbody>
</table>

A Ampacity of single-conductor cable in air at ambient temperature of 30°C and maximum conductor temperature not exceeding 60°C.

R Temperature correction: the conductor resistance may be corrected for moderate temperature differences from the noted reference temperature by the following equation. The parameter, \( \alpha T \), varies with conductivity and temperature. For a list of common temperature coefficients see Test Methods B 193.

\[
R_T = R_t [ 1 + \alpha_T (T - t) ]
\]

where:

- \( R_T \) = resistance at reference temperature \( T \),
- \( R_t \) = resistance as measured at temperature \( t \),
- \( \alpha_T \) = known or given temperature coefficient of resistance of the conductor being measured at reference temperature \( T \). At 20°C, the value is 0.003 93,
- \( T \) = reference temperature, and
- \( t \) = temperature at which measurement is made.

An asterisk (*) indicates preferred sizes for wires of American Wire Gauge or per IEC 60228 (metric) as appropriate.
Standard Specification for
Pneumatic-Operated, Globe-Style, Control Valves

This standard is issued under the fixed designation F 1985; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, construction, testing, and operating requirements for pneumatic-operated, globe-style, control valves complete with actuators for various fluid systems (steam, gas, and liquid applications). The control valves with actuators may be procured under this specification complete with all associated pneumatic instrumentation necessary for the valve to function in the system application; however, complete and detailed requirements for air instrumentation are beyond the scope of this specification and thus are not included here. This specification is not intended to cover quarter-turn or multi-turn stem valves.

1.2 The values stated in metric units (SI) are to be regarded as standard. The values given in parenthesis (inch/pound) are provided for information purposes.

2. Referenced Documents

2.1 The most recent edition or revision of the following standards or specifications shall, to the extent specified in this specification, form a part of this specification.

2.2 ASME Standards:
- B1.1 Unified Screw Threads (UN and UNR Thread Form)²
- B1.20.1 Pipe Threads, General Purpose (Inch)²
- B16.1 Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800²
- B16.5 Pipe Flanges and Flanged Fittings²
- B16.11 Forged Steel Fittings, Socket-Welding and Threaded²
- B16.25 Butt welding Ends²
- B16.24 Bronze Pipe Flanges and Flanged fittings, Class 150 and 300²
- B16.34 Valves - Flanged and Butt welding End Steel, Nickel Alloy, and Other Special Allows²

2.3 Manufacturers Standardization Society of the Valve and Fitting Industry:
- MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions³
- FCI 70-2 Control Valve Seat Leakage⁴
- 2.5 Military Standards and Specifications:
  - MIL-STD-798 Nondestructive Testing, Welding Quality Control Material Control and Identification and Hi-Shock Test Requirements for Piping System Components for Naval Ship Use⁵
  - MIL-S-901 Shock Tests, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for⁵
  - MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I– Environmental and Type II – Internally Excited)⁵
  - MS-16142 Boss Gasket-Seal Straight Thread Tube Fitting, Standard Dimensions for⁵
  - MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver Brazing, General Specification for⁵
  - MIL-F-20042 Flanges, Pipe and Bulkhead, Bronze (Silver Brazing)⁵

2.6 Government Drawings and Publications:
- Naval Sea Systems Command (NAVSEA):
  - 803-1385946 Unions, Bronze, Silver Brazing Alloy. For Water, Oil, and Gas⁵
  - 803-1385943 Unions, Silver Brazing, 3000 lb/in.², WOG, NPS, for UT Inspection
  - 803-1385884 Unions, Butt and Socket Welding, 6000 lb/in.² WOG, NPS, For UT Inspections⁵

2.7 ISA Standard:
- ISA-S75.05 Standard for Control Valve Terminology⁶

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

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² This specification is under the jurisdiction of ASTM committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


⁴ Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.


⁶ Available from International Society for Measurement and Control, 67 Alexander Dr., PO Box 12277, Research Triangle Park, NC 27709.
3.1.1 actuator—the unit that converts a pneumatic pressure signal into a force to position the valve plug.

3.1.2 bonnet—the upper portion of the valve body subassembly to which the yoke attaches. The bonnet contains the valve stem packing.

3.1.3 dead band—the range through which input signal can be varied, upon reversal of direction, without an observable change in the valve stem position.

3.1.4 equal-percentage opening—an equal-percentage flow characteristic of a control valve provides a change in flow, with the change in valve lift, that is a constant percentage of the flow before the change was made.

3.1.5 flow coefficient \( (C_V) \)—A basic capacity rating for valves that relates flow rate to the inlet and outlet pressure for a particular fluid in the full-open position of the valve. It is defined as the number of litres per seconds (gallons/min) of 16°C (60°F) water that will flow through the valve with a 6.9 kPa (1 psi) pressure drop (\( \Delta p \)) across the valve.

3.1.6 globe-style valve—a basic control valve type that gets its name from the globular shape of its body. It normally uses a basic rising stem/plug for the closure member.

3.1.7 hydrostatic shell test pressure—the hydrostatic test pressure that the valve body is required to withstand without damage or leakage. Valve operation is not required during application of this test pressure, but the valve shall meet all performance requirements after the pressure has been removed.

3.1.8 hysteresis—the maximum difference in output value for any single input value during a calibration cycle, excluding errors as a result of dead band.

3.1.9 instrumentation—the term instrumentation, when used in this specification, refers to any instrumentation, that is, pilot controllers, transmitters, relays, selectors, positioners, instrument air reducing valves, and strainers/filters required for operation of the control valve in the system.

3.1.10 internal trim—internal parts of the control valve, including seat rings, plug, stem, guide bushings, cage, pistons, and so forth.

3.1.11 linear-opening—a linear-opening flow characteristic of a control valve provides a change in flow that is linearly proportional with valve lift.

3.1.12 linearity—the measure of how close a plot of the valve stem travel (in response to an increasing and a decreasing input signal) conforms to a straight line. Linearity is normally expressed as the ratio (in percentage) of the maximum deviation from a straight line connecting the end points of the full operational valve stem stroke.

3.1.13 manual override—the manual override allows valve operation manually. The manual override feature has the ability to oppose and overcome an opening or closing pneumatic control signal in controlling valve position.

3.1.14 pneumatic-operated control valve—a valve installed directly in the fluid system, which translates a pneumatic signal into a change in flow resistance for the system fluid.

3.1.15 pressure rating—the pressure rating of the valve shall be as defined in the documents listed in Table 1. The pressure ratings (also called pressure-temperature ratings) establish the maximum allowable working (service) pressures of a component (valve, end connections, and so forth) at various temperatures.

3.1.16 quick change cage trim—a gasket or an O-ring used in this specification, refers to any instrumentation, that is, pilot controllers, transmitters, relays, selectors, positioners, instrument air reducing valves, and strainers/filters required for operation of the control valve in the system.

3.1.17 quick-opening—a quick-opening flow characteristic of a control valve provides large changes in flow for small changes in valve lift.

3.1.18 rangeability—a measure of the usable range of a control valve and defined as the ratio of the maximum to the minimum controllable \( C_V \). These maximum and minimum controllable \( C_V \) establish the throttling range over which a given control characteristic can be maintained and within which the valve can perform a useful throttling function.
3.1.19 *travel indicator*—the moving pointer mechanically attached to the valve stem and working in conjunction with a fixed indicator scale attached to the yoke.

3.1.20 *three-way valve*—a three-way valve has three end connections configured for converging or diverging flow.

3.1.21 *valve body subassembly*—the combination of valve body, bonnet, end connections, and internal trim.

3.1.22 *yoke*—the intermediate piece between the valve bonnet and the actuator.

3.2 Additional guidance on the control valve terminology can be found in ISA-S75.05.

4. Classification

4.1 Valves shall be of the following material grades, pressure ratings, types, seat leakage classes, flow characteristics, and sizes, as specified in Section 5.

4.1.1 Material Grades (Applicable to Pressure Containing Parts Only):

4.1.1.1 Grade *A*—Alloy Steel—Material Group 1.9 of ASME B16.34 (1 Cr-½ Mo, or 1-¼ Cr-½ Mo).

4.1.1.2 Grade *B*—Carbon Steel—Material Group 1.1 of ASME B16.34.

4.1.1.3 Grade *C*—Corrosion-Resistance Stainless Steel—Material Group 2.2 of ASME B16.34 (18 Cr-8 Ni alloy).

4.1.1.4 Grade *D*—As specified in the ordering information (see Section 5).

4.2 *Pressure Ratings*—Valve shall have pressure ratings selected from those listed in Table 1 and specified in Section 5.

4.3 Types:

4.3.1 Type *1*—Two-way valve, in-line (two end connections).

4.3.2 Type *2*—Two-way valve, angle (two end connections).

4.3.3 Type *3*—Three-way valve, converging service (three end connections—two inlet and one outlet end connections).

4.3.4 Type *4*—Three-way valve, diverging service (three end connections—one inlet and two outlet end connections).

4.4 *Seat Leakage Classes (Maximum Allowable Seat Leakage)*—Seat leakage class shall be selected from those listed in FCI 70-2 and specified in Section 5.

4.5 *Flow Characteristics*—The inherent flow characteristics of the valve shall be specified as quick-opening, linear-opening, equal-percentage opening, or as specified in Section 5. (Additional guidance on valve flow characteristics can be found in ISA Handbook of Control Valves).

4.6 *End Connections*—Valve shall have end connections selected from those listed in Table 1 and specified in Section 5.

4.7 *Sizes*—Valve size shall be as specified in Section 5.

5. Ordering Information

5.1 Ordering documentation for valves under this specification shall include the following information, as required, to describe the equipment adequately:

5.1.1 ASTM designation and year of issue,

5.1.2 Material grade (see 4.1 and Table 1),

5.1.3 Pressure rating (see 4.2),

5.1.4 Pressure drop (Δp), kPa (psi),

5.1.5 Type (see 4.3),

5.1.6 Seat leakage class (see 4.4),

5.1.7 Flow characteristics (see 4.5),

5.1.8 End connections (see 4.6),

5.1.9 Size, inlet, and outlet (see 4.7),

5.1.10 Rangeability (see 7.2),

5.1.11 Line medium (see 6.2),

5.1.12 Operating pressures of the line media (minimum, normal, and maximum) (see 6.16),

5.1.13 Inlet temperature of the line media (minimum, normal, and maximum) (see 6.16),

5.1.14 Flow rate required (minimum, normal, and maximum) (see 7.1),

5.1.15 Replaceable seat ring requirement (see 6.13),

5.1.16 Minimum available air supply pressure to the actuator (see 6.16),

5.1.17 Minimum and maximum actuator control signal pressure, kPa (psi) (benchset of the actuator),

5.1.18 When manual override feature is required, its location—top or side-mounted (see 6.14.3),

5.1.19 Valve fail-position required upon loss of air supply to the actuator (see 6.14.4)

5.1.20 Instrumentation requirements (see 6.15),

5.1.21 Supplementary requirements, if any (see Supplementary Requirements, S1, S2, or S3).

6. Valve Construction

6.1 Valves shall incorporate the design features specified below:

6.1.1 *General Requirements*:

6.1.1.1 Design shall permit adjustment without requiring removal of the valve body from the line.

6.2 *Materials of Construction*—Materials for pressure-containing parts shall be in accordance with the applicable documents listed in Table 1 (see 4.1). Materials for internal parts shall be compatible with the line media specified in Section 5.

6.3 *Pressure Envelope*—The control valve shall be designed to pass a hydrostatic shell test at pressure(s) of at least 1.5 times the 38°C (100°F) pressure rating(s) of the valve without damage.

6.4 *Joints*—The bonnet and bottom cover/flange shall be attached to the body using bolted flanges, a threaded connection, or a threaded-union connection.

6.5 *Valve Springs*—Any spring incorporated in the control valve shall not be compressed solid during operation. Spring ends shall be squared and ground.

6.6 *Threads*—Threads shall be as specified in ASME B1.1. Where necessary, provisions shall be incorporated to prevent the accidental loosening of threaded parts. The design shall be such that standard wrenches can be used on all external bolting. Lock-wire shall not be used. Any exposed threads shall be protected by plastic caps for shipping.

6.7 *Interchangeability*—The control valve, including all associated piece parts, shall have part number identity and shall be replaceable from stock by the manufacturer on a nonselective and random basis. Parts having the same manufacturer’s part number shall be directly interchangeable with each other with respect to installation (physical) and performance (functional). Physically interchangeable assemblies, components, and parts are those that are capable of being readily installed, removed, or replaced without alternation, misalignment, or
damage to parts being installed or to adjoining parts. Fabrication operations such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall not be required.

6.8 Nonmetallic Element Interchangeability—Nonmetallic elements, including but not limited to, soft-seating inserts, cushions, and O-rings, shall be treated as separately identified and readily replaceable parts.

6.9 Maintainability—Maintenance shall require standard tools to the maximum extent possible. Any special tools required for maintenance shall be identified and shall be supplied with the valve when specified.

6.10 Reversibility—Seating inserts shall not be physically reversible unless they are also functionally reversible to preclude incorrect assembly.

6.11 Pressure-Temperature Ratings—Valve pressure-temperature ratings shall be in accordance with the documents listed in Table 1.

6.12 Stem Seal Assembly—A stem seal assembly shall be provided to seal against leakage along the stem. The stem seal design shall allow the removal of the actuator assembly without disturbing the stem seal assembly.

6.13 Seat Ring—Where required by the service, a seat ring shall be incorporated in the valve and shall be of a material different from the valve body to provide increased resistance to wear, erosion, and leakage. The method of installation of the seat ring shall ensure against dislodgment of the seat ring or leakage between the seat ring and the valve body. Where a replaceable seat ring is required, it shall be specified in Section 5. Unless the method of seat ring retention (for example, quick change cage trim, threaded, brazed, threaded and seal welded, and so forth) is specified in Section 5, it shall be per manufacturer’s standard.

6.14 Actuator Assembly:

6.14.1 Yoke—Yoke construction shall allow easy access to the stuffing box, stem connection, and spring adjuster from either side of the valve. Mounting pads shall be provided on the opposite sides of the yoke for mounting valve positioners or other accessories or both.

6.14.2 Travel Indicator—A travel indicator shall be provided to indicate the valve closure member position.

6.14.3 Manual Override—When specified (see Section 5), manual override shall be furnished. Location (top- or side-mounted handwheel) shall be as specified (see Section 5). A clockwise rotation of the handwheel shall close the valve. The maximum rim force required on handwheel shall not exceed manufacturer’s standards.

6.14.4 Fail-Position Requirement—In the event of loss of actuator air supply, the valve shall proceed to and remain in fail-open, fail-close, or fail-in-position as specified in Section 5.

6.15 Instrumentation—When specified (see Section 5), the valve manufacturer shall furnish with the valve the instrumentation necessary to accomplish the required control functions. The process and pneumatic connection(s) to controller’s pilots or transmitters shall be specified in the ordering data. Intermitent bleed instrumentation shall be used wherever it is compatible with performance, sensitivity, and response speed requirements. Instrumentation interface requirements shall be specified in Section 5.

6.16 Valve Operation—The valve shall operate properly at the operating conditions specified in Section 5. Operating conditions such as operating pressure of line medium, Δp, inlet temperature, and air-supply pressure to actuator shall be supplied in Section 5.

7. Performance

7.1 All valves shall meet the requirements of 7.1.1-7.7.

7.1.1 Capacity—The valve shall be capable of passing the maximum flow rate specified or any intermediate flow rate within the rangeability specified (see Section 5).

7.2 Rangeability—The valve shall exhibit the rangeability specified in the ordering data (see Section 5).

7.3 External Leakage.

7.3.1 Valve—There shall be no visible external leakage from the pressure boundary.

7.3.2 Actuator—There shall be no leakage in the actuator assembly.

7.3.3 Stem—There shall be no visible leakage past the stem.

7.4 Internal Seat Leakage—The seat leakage shall not exceed the leakage specified in FCI 70-2 for its seat leakage class specified in Section 5 (see 4.4).

7.5 Hysteresis—Hysteresis shall not exceed 2 % of valve stroke for valves supplied with or without instrumentation installed.

7.6 Dead Band—Under operating conditions, the dead band shall not exceed 2.4 kPa (0.35 psi) within the full stroke of the stem.

7.7 Linearity—The linearity shall not exceed ±3 % with the instrumentation installed, if the instrumentation is specified in Section 5.

8. Tests Required

8.1 Each control valve shall pass the tests outlined in 8.1.1-8.5.

8.1.1 Visual Examination—The control valve shall be examined visually to determine conformance with the ordering data, interface dimensions, and workmanship without disassembly.

8.2 Hydrostatic Shell Test—Each control valve shall be hydrostatically tested in the partially open position, by applying a test pressure of not less than 1.5 times the 38°C (100°F) pressure rating to the inlet and outlet ports to check structural integrity. Test pressure(s) shall be applied for 3 min. Air or nitrogen may be used in lieu of water, providing appropriate safety precautions are taken to minimize the risk associated with the use of a compressible fluid. There shall be no external leakage (excluding stem-packing leakage), permanent distortion, or structural failure.

8.3 Nondestructive Examination (NDE)—When specified in Section 5, NDE requirements shall be met by performing tests in accordance with the commercial practices listed in ASME B16.34. This shall include radiography testing, magnetic particle testing, dye penetrant, or ultrasonic testing and visual testing as delineated in the above specification.
8.4 Seat Leakage Test—A seat leakage test shall be conducted to verify conformance with the internal seat leakage allowed in 7.4.

8.5 Functional Test—With air pressure applied to the valve actuator, the valve shall be stroked through its entire range of stem travel. Stem travel shall be smooth without sticking or binding. Thereafter, with no air pressure applied to the valve inlet port, the valve shall be tested to verify the minimum air pressure required to initiate stem travel and the maximum air pressure required to complete its full stroke. Air pressure requirements to stroke the valve shall be based upon the operating conditions specified in the ordering information (see Section 5).

9. Marking

9.1 Markings—Valves shall be marked in accordance with MSS SP-25.

10. Quality Assurance System

10.1 The valve manufacturer shall establish and maintain a quality control program following the principles of an appropriate standard from the ISO 9000 series. The need for registration or certification by an independent organization for the valves manufactured under the quality control program shall be determined by the manufacturer. Documentation demonstrating quality control program compliance shall be available to the purchaser at the facility at which the valves are manufactured. A written summary shall be available to the purchaser upon request. The valve manufacturer is the corporate entity whose name or trademark appears on the valve.

10.2 The purchaser reserves the right to witness the production tests and inspect the valves in the manufacturer’s plant to the extent specified on the purchase order.

11. Technical Data Requirements

11.1 Drawings—Assembly drawings, information sheets, or catalog sheets shall be provided to indicate the design and materials used in the valve for approval by the purchaser.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements, S1, S2, or S3 shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of those supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Supplemental Tests

S1.1 Supplemental tests shall be conducted at a facility satisfactory to the customer and shall consist of the examinations and tests selected from those specified in S1.1 through S1.5 and delineated in the ordering data. The supplemental tests may be conducted only on representative valve sizes and pressure classes to qualify all sizes and pressure classes of valves, provided the valves are of the same type and design. Evidence of prior approval of these tests may be acceptable.

S1.1.1 Flow Tests—A flow test shall be conducted to determine the valve $C_v$ and the flow characteristic of the control valve.

S1.2 Operational Tests:

S1.2.1 The valve shall be operationally tested as follows:

S1.2.1.1 The valve shall be assembled. Stuffing box nuts shall be finger tight with packing installed or with the packing removed; the valve body shall be at atmospheric pressure. Tapping the valve to remove friction is not permitted.

S1.2.1.2 Hysteresis shall be tested at 25 and 75 % of stroke. At any stroke position, a change of air pressure of 1.7 kPa (0.25 psig) (excluding dead band) in either direction shall cause the valve stem to move. If an automatic hysteresis loop record is obtained, the maximum difference in valve position between increasing and decreasing pressures shall not exceed 2 % of stroke (see 7.5).

S1.2.1.3 Linearity of travel shall be tested at 0, 25, 50, 75, and 100 % of stroke. The relationship between air pressure and stem travel shall be linear to within ±3 % (see 7.7).

S1.3 Shock Test—The control valve shall be subjected to the high-impact shock tests as specified in MIL-S-901 and MIL-STD-798 while pressurized with water, air, or nitrogen to determine its resistance to high-impact mechanical shock. The detail requirements of MIL-S-901 and MIL-STD-798 shall be delineated in the ordering information. There shall be no visible structural damage to the control valve or any of its components. There shall be no degradation to the performance capability of the control valve. During impact, an instantaneous, reversible pressure excursion is allowable.

S1.4 Vibration Test—Control valve shall be vibration tested in accordance with Type I of MIL-STD-167-1 while pressurized with water, air, or nitrogen gas. The detail requirements of MIL-STD-167-1 shall be delineated in the ordering information. There shall be no visible structural damage or degradation to the performance capability of the control valve.

S1.5 Posttest Examination—After completion of the shock and vibration testing, the control valve shall be disassembled and material conditions noted. If shock and vibration tests are done successively in sequence, it is not necessary to disassemble and inspect the valves in between the tests.

S2. Technical Data Requirements

S2.1 Drawings—Assembly drawings or catalog sheets of the control valve that clearly depict design and material of each part shall be provided.

S2.2 Technical Manuals—A technical manual or instruction booklet shall be provided which provides a description of the
valve, operation and maintenance instructions, calibration valves, and illustrated parts breakdown. It shall include wrench sizes and assembly torque (or equivalent) for all bolting and threaded assemblies and step-by-step disassembly and reassembly procedures.

S3. Special Material, Design, and Performance Requirements

S3.1 Pipe threads shall not be used in control valve construction.

S3.2 Control valve performance shall not be adversely affected by the following line and ambient conditions:

S3.2.1 Quality of Inlet Air/Gas—Air or nitrogen moisture content between the limits of −7°C (20°F) to −51°C (60°F) saturated at maximum rated pressure.

S3.2.2 Ambient Atmospheric Conditions:

S3.2.2.1 Temperature—4°C (40°F) to 49°C (120°F).

S3.2.2.2 Moisture Content—Exposure to atmosphere containing salt-laden moisture.

S3.3 Air Connections—Air connections between the pilot controller, actuator, and other accessories shall be in accordance with MS 16142, straight-thread and O-ring seal.
1. Scope

1.1 This test method covers shipboard, fixed (installed) foam/sprinkling firefighting systems.

1.2 Satisfactory completion of these tests indicates functional performance of the fixed foam firefighting system and may be used to demonstrate the system installation’s compliance with the design characteristics of the system.

1.3 Tests made in conformity with this test method are intended to demonstrate the installation and operation of an installed, fixed foam firefighting system. As it includes regulatory requirements, this standard addresses those vessels subject to regulations and ship classification rules. However, the methods stated herein are suitable for unregulated commercial vessels, pleasure craft, military vessels, and similar vessels that are not required to meet regulations for firefighting systems.

1.4 Limitations:

1.4.1 International requirements, national regulations, and ship classification rules must be consulted. The following regulatory requirements and classification society rules were considered in the preparation of this test method:


1.4.1.2 U.S. Government regulations included in 46 CFR 76, 46 CFR 95, and 46 CFR 108 as those regulations are written and enforced by the United States Cost Guard, and

1.4.1.3 The American Bureau of Shipping (ABS) Rules for Building and Classing Steel Vessels. However, the owner will designate the specific classification society which is to be used to classify a particular vessel.

1.4.2 The requirements, regulations, and rules for a specific design must be selected by the owner based on the planned operating profile for the vessel.

1.4.3 This test method reflects international requirements, U.S. Government regulations, and ABS rules in effect at the time it was prepared, and may not include requirements adopted subsequent to the effective date of this test method.

1.4.4 This test method does not include requirements for the selection, design, installation, and maintenance of foam firefighting systems. It applies to installed systems whose designs meet all applicable international requirements, national regulations, and ship classification rules.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 The following documents apply to this test method only to the extent referenced herein. However, they may be further invoked by the ship owner as part of the design requirements for the vessel.

2.2 ASTM Standards:

A 795 Specification for Seamless Steel Pipe for Fire Protection Use

F 998 Specification for Centrifugal Pumps, Shipboard Use

F 1030 Practice for Selection of Valve Operators

F 1155 Practice for Selection and Application of Piping System Materials

F 1198 Guide for Shipboard Fire Detection Systems

F 1333 Specification for Construction of Fire and Foam Station Cabinets

F 1370 Specification for Pressure-Reducing Valves for Water Systems, Shipboard

F 1508 Specification for Angle Style, Pressure Relief Valves for Steam, Gas, and Liquid Services

F 1510 Specification for Rotary Positive Displacement Pumps, Commercial Ships Use

F 1547 Guide Listing Relevant Standards and Publications for Commercial Shipbuilding

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1 This test method is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.


2 Annual Book of ASTM Standards, Vol 01.01.

2.3 Code of Federal Regulations (CFR): 4
Title 46, Part 76, Fire Protection Equipment, Subpart 76.17, Foam Extinguishing Systems, Details
Title 46, Part 76, Subpart 76.23, Manual Sprinkling System, Details
Title 46, Part 95, Fire Protection Equipment, Subpart 95.17, Foam Extinguishing Systems, Details
2.4 ABS Rules for Building and Classing Steel Vessels: Part 4, Section 6 Pumps and Piping Systems
Part 4, Section 9 Fire Extinguishing Systems
Part 4, Section 11 Shipboard Automatic and Remote-control Systems
5/4B.11 Fire Protection and Fire Extinction
2.5 IACS Documents:
Comparable rules also are published by other members of the International Association of Classification Societies
2.6 IMO SOLAS Regulations:
2.7 ANSI Standard:
B16.34 Small Butt Welding End Valves
2.8 NFPA Publications:
NFPA 11 Standard for Low Expansion Foam
2.9 SNAME Bulletins:
3. Terminology
3.1 Refer to Annex A1 for terminology used in this test method related to fixed foam firefighting system installations and their testing. Actual terminology used for fixed foam firefighting systems may vary depending upon the desires of the owner or system designer, or both.

4. Significance and Use
4.1 This test method is applicable to fixed foam firefighting systems, including foam generation equipment, foam distribution system piping and valves, sprinkler arrangement and operation, hose reel unit operation, and system controls, as those components are included in the system for a particular application.

4.1.1 Foam systems for machinery spaces are tested using those portions of this test method which apply to the installed components. Suitable adaptation of this test method is made for use with systems which do not include all hardware components described herein.

4.1.2 Deck foam systems are tested per the manufacturer’s design criteria.

4.2 This test method demonstrates: satisfactory installation of an entire fixed foam/sprinkling system and its associated controls; and effective operation of portions of the foam distribution system and foam maker sprinkling nozzles for selected zones.

4.2.1 This test method verifies application rates and areas of coverage for each type of discharge device of the fixed foam firefighting system.

4.2.2 The satisfactory operation of the system in the selected zones is a measure of overall system capacity and anticipated operation for emergency use. The test, however, may not be representative of all emergency operating conditions that may vary with changes in the number of zones that are activated simultaneously, the material condition of the distribution and sprinkling components as they are maintained over time, and restoration of the system following its use for testing or actual emergencies.

4.3 Test procedures shall be prepared for the conduct of tests of foam firefighting systems in specific vessels. Those procedures shall be tailored to the system design for the system as installed and operated in each vessel.

4.3.1 Tests accomplished in accordance with approved test procedures may be sufficient to demonstrate that the vessel meets the regulatory and classification requirements for the vessel.

4.3.2 Approval of test procedures by a classification society may be necessary.

4.3.3 Test procedures must state operating parameters and values (for example, flow rate, pressure, time to activate) which define pass/fail criteria for each test.

4.4 Certification of the vessel or classification of the vessel or both by the regulatory bodies may require that tests be witnessed by a marine inspector or surveyor or both who represents both regulatory bodies.

4.5 Interpretation of Results:
4.5.1 Leakage at any piping system mechanical joint that is corrected “on-the-spot” is not cause for test rejection.

4.5.2 Any erratic operation detected in the zone control valves, seawater sprinkling pump discharge bypass-overboard valves, or control devices is cause for rejection of the test. The component causing the erratic operation shall be repaired or replaced and a retest performed.

4.5.3 Any operation which does not meet the pass/fail criteria defined by the test procedure(s) is cause for rejection of the test. The cause of the failure shall be determined, the design or installation, or both, corrected as appropriate, and a retest performed.

5. Hazards
5.1 Safety Hazards—The following safety precautions must be taken when conducting tests in accordance with test procedures that conform with this test method. However, this is...
not an inclusive listing of all hazards which may occur when
this test method is followed, see 1.5. Appropriate safety hazard
statements must be included in test procedures that conform
with this test method.

5.1.1 Live control circuits are exercised during tests per-
formed in accordance with this test method. This can result in
the inadvertent discharge of seawater or seawater/foam solu-

5.1.1.1 Remote operation of valves which allow discharge
of fluids directly into interior spaces of the vessel is required.
5.1.1.2 Tag out electrical circuits or tag closed valves as
appropriate for each test.
5.1.2 The fixed foam firefighting system includes relief
valves and pressure-regulating valves which limit the internal
pressures to which piping and valves of the system are
subjected. Failure of these devices to control or limit system
pressure may result in component failures.
5.1.3 The following safety and control devices are required
to conduct the tests:
5.1.3.1 Pumps’ relief valves;
5.1.3.2 Seawater sprinkling pump discharge bypass-
overboard relief valves which must be set in accordance with
the maximum system operating pressure; and
5.1.3.3 Zone sprinkling control, remotely operated valves,
as applicable.
5.1.4 All precautions to ensure safety of life and equipment
protection in compliance with the industrial facility’s and
vessel’s established safety precautions shall be followed at all
times in the conduct of foam firefighting system tests.
5.1.5 Portions of the fixed foam firefighting system should
not be disabled or isolated for tests until just before the a
specific test event is scheduled to commence. This will leave
the system functional for use in case of an actual fire.
5.2 Precautionary Statements—The following precautions
should be taken when conducting tests in accordance with test
procedures which conform with this test method. Appropriate
precautions and warning statements must be included in test
procedures that conform with this test method.
5.2.1 All appropriate electrical circuits must be de-
energized and tagged when doing any test or demonstration
involving contact with electrical conductors.
5.2.2 It is against environmental regulations to discharge
seawater/foam solutions within 3 miles of shore in the United
States. Care must be taken to prevent discharge of foam into
coastal waters of any country. Therefore, all in-port testing is to
be accomplished using fresh water or clean seawater. Foam
concentration testing, by dispersion of actual seawater/foam
solution, is to be accomplished only when underway, well
outside coastal waters, or the seawater/foam solution is dis-
charged to a containment vessel for disposal in conformance
with local regulations.
5.2.3 Sprinkling or other discharge into interior spaces can
lead to water or seawater/foam solution accumulation. Vessel
stability can be dangerously affected if dewatering systems are
not fully functional and operating. Operators must closely
monitor the amount of water accumulated on deck during any
phase of demonstrations or testing. Demonstrations or testing
should be suspended if such accumulation cannot be controlled
and sufficient stability maintained.
5.2.4 All equipment or surfaces that could be damaged by
water during testing, in way of hose reel discharge areas or in
zones where fresh water or seawater/foam solutions will be
discharged from foam maker sprinkling nozzles, or both,
should be covered with plastic or otherwise protected from the
discharge.
5.2.5 Any piping flanges that formerly were blanked to
conduct hydrostatic testing of the foam distribution system
should be inspected for tightness during the operational tests.
5.2.6 Precaution shall be taken to ensure proper valve
alignment to prevent flooding the vessel during any test
requiring operation of the seawater sprinkling system, seawater
sprinkling pumps, foam proportioning pumps, and foam con-
centrate transfer pumps.
5.2.7 Any tests requiring seawater or seawater/foam solu-
tion to be pumped through foam distribution system piping
shall be conducted only after precautions have been taken to
insure the watertight integrity at the maximum system operat-
ing pressure of all affected piping and valves.
5.2.8 Appropriate zone control valves shall be tagged closed
during in-port testing to preclude accidental discharge of foam
concentrate entering the distributive system or being dis-
charged overboard.
5.2.9 Isolate system areas or zones that are not used in a
specific test.
5.3 Remedial Statements—System restoration following
demonstrations should include the following actions.
5.3.1 Restore all electrical power to the pumps and controls.
Ensure that all electrical and control circuits are set for normal
operation.
5.3.2 Ensure that tags installed on remotely operated valves
have been removed.
5.3.3 Ensure that all distribution piping and valves are
aligned for normal operation.
5.3.4 Clean up all areas and equipment that may have been
wetted by sprinkling or flooding incidental to these demonstra-
tions.
5.3.5 Remove any “socks” or other devices installed to
contain water or foam discharged during demonstrations.
5.3.6 Remove any test instrumentation or gauges installed
for the demonstrations.
5.3.7 Ensure that foam concentrate tanks are filled with
foam concentrate.

6. Overview of Fixed Foam Firefighting System Tests
6.1 There are two phases of testing the fixed foam and
seawater sprinkling system: system installation tests and sys-
tem operational tests.
6.2 Installation testing is intended to demonstrate the integ-
rity of the system as it was installed in the vessel. It comprises
a series of tests to demonstrate that the foam/sprinkling system
is completely installed. It is essential that this testing be
completed before accomplishing any operational tests using
seawater or foam.
6.3 Operational testing is intended to demonstrate that the
system operates in each of its designed modes of operation.
System operational testing is accomplished through a series of
individual tests to exercise all elements of the system. Some tests will be performed with the vessel in port; other tests will be done with the vessel underway.

7. Prerequisite Requirements

7.1 The following test materials are required to conduct the test:

7.1.1 Freshwater, sufficient to fill repeatedly all foam concentrate tanks for in-port tests.

7.1.2 Foam maker pressure test fittings composed of the following: adaptors to install the fitting in-line with a sprinkler nozzle with branch connection to a globe needle valve and pressure gage.

7.1.3 Sufficient foam concentrate to conduct demonstrations and tests called for within this standard.

7.2 The following equipments and systems are involved in the testing. Required testing of individual equipments shall have been completed before testing the foam firefighting system.

7.2.1 All seawater and sprinkling/foam distribution system and transfer system piping in the foam firefighting system.

7.2.2 All installed foam proportioners and foam concentrate tanks.

7.2.3 Foam concentrate, foam concentrate transfer, and seawater sprinkling pumps.

7.2.4 Foam maker sprinkling nozzles, hose reels, and zone control valves.

7.2.5 Damage control console (DCC) or other central control station operating controls, local control station control panels, and fire control station operating controls.

8. Preparation for Testing

8.1 The following prerequisite testing shall have been completed satisfactorily before commencing system tests of the foam firefighting system.

8.1.1 Control System—Testing of the central control station’s DCC, including any remote alarms or operations conducted through the DCC, shall have been completed using any separate test procedures developed for that equipment.

8.1.1.1 Such testing may be accomplished in accordance with Guide F 1198 and should meet the test requirements of that guide.

8.1.1.2 Ensure continuity of all electrical signal or fiber optic cable connections from the DCC to each remotely operated valve and its associated local control panel, the fire control station, and each foam proportioning station and its associated pumps and valves.

8.1.2 Piping and Valves—Testing of individual piping runs and valves, including hydrostatic tests, shall have been completed using any separate test procedures developed for fluid distributive systems. Documentation should be provided before starting the foam system tests.

8.1.2.1 Pipe and valves used for foam distribution should meet the test requirements of the material specifications for items cited by Table 10, “Dry Fire Main, Foam, Sprinkling, Deckwash, Tank Cleaning Piping,” of Practice F 1155.

8.1.2.2 The piping associated with foam proportioners seawater valves should meet the testing requirements of Specification A 795.

8.1.2.3 Remotely operated valve operators should be meet the testing requirements of Practice F 1030.

8.1.2.4 Pressure regulating valves should meet testing requirements for pressure-reducing valves such as those found in Specification F 1370.

8.1.2.5 Relief valves, when a component of piping systems, should meet the test requirements of Specification F 1508.

8.1.2.6 Butterfly-type quick acting valves should meet the testing requirements of ANSI B16.34.

8.1.3 Operating Stations—Testing of the following operating stations to ensure electrical power is available, continuity of electrical signal or fiber optic cable connections between the DCC and the remotely controlled valve(s) or pumps, and proper operation of the control consoles or panels at each station shall have been completed using any separate test procedures developed for that equipment.

8.1.3.1 Fire control station, including signal connections to the foam proportioning stations,

8.1.3.2 Foam proportioning stations,

8.1.3.3 Zone control stations, including signal connections to the foam proportioning stations, and

8.1.3.4 Hose reel unit controls, including signal connections to the foam proportioning stations.

8.1.4 Foam Transfer Stations—Testing of individual components, including hydrostatic tests, shall have been completed using the separate test procedures for foam transfer stations. Pipe and valves used for foam transfer should meet the testing requirements of the material specifications for items cited by Table 10, “Dry Fire Main, Foam, Sprinkling, Deckwash, Tank Cleaning Piping,” of Practice F 1155.

8.1.5 Test relief valves and pressure-regulating valves for proper settings. Components such as pumps that have integral relief valves or bypass valves may have such valve settings verified as part of testing that component.

8.2 The following actions shall have been completed before commencement of tests of the applicable portions (or all) of the foam firefighting system. (Warning—Safety procedures shall be followed to tag out electrical circuits or tag closed valves as appropriate for that portion of the test.)

8.2.1 Isolate system areas that are not used in a specific portion of the test. (Warning—Close and tag valves to isolate portions of the system including zones and hose reel units that will not be tested. Visually confirm all designated valves are closed.)

8.2.2 Install the test fittings (see 7.1.3) in the hydraulically most remote foam maker nozzles between the reducer from the branch connection and the nozzle inlet. Install pressure gages. Adjust the isolation valves as necessary during conduct of the test to obtain readings without excessive pressure fluctuation or water hammer.

9. Conduct of System Tests

9.1 Foam Concentrate Tank Hydrostatic Test—Verify there is a certification of the tank that it will withstand, at a minimum, the hydrostatic pressure to be seen as it is installed in the system. Lacking such certification, the foam concentrate tank shall be tested as follows.

9.1.1 Temporarily blank all openings except the overflow piping. Fill the tank with fresh water to the top of the overflow
9.1.2 Upon completion of the hydrostatic test, remove all temporary blanks or plugs, or both. Freshwater may be retained for use during pump operational tests and hose reel tests.

9.1.3 All tanks and associated piping must be drained of all water before the introduction of foam concentrate into the tanks.

9.2 Pump Installation Test—Each seawater sprinkling pump and foam concentrate pump shall be tested.

9.2.1 Ensure that each pump and motor shaft alignment is completed and that the pump rotates freely when turned by hand.

9.2.2 Verify integrity of all piping and electrical connections to each pump and its motor.

9.3 Pump motor and controller operational tests: each seawater sprinkling pump, foam concentrate pump, and foam concentrate transfer pump shall be tested.

9.3.1 Perform insulation resistance checks before (cold) and after (hot) the operational test. (Warning—Ensure all electrical power is secured to pump motors before conducting insulation resistance checks.)

9.3.2 Conduct an operational test with the pump and motor unit running and the system aligned to provide continuous operation. Pump and motor operation shall be without indications of internal rubbing (for example, noise or vibration) or other external signs of degrading performance. Pump output pressure shall be constant over the operating period. Motor amperage shall not exceed name plate data during steady state operation.

9.3.3 Additional requirements for seawater sprinkling pump tests. (Warning—Ensure seawater isolation valves to the foam proportioners and its seawater bypass are closed and tagged.)

9.3.3.1 Align the pump to take suction from the sea and discharge overboard.

9.3.3.2 Seawater sprinkling pump relief valves should be set at the design operating pressure. Pressure control valves should be adjusted so that the valves control pressure changes to design criteria.

9.3.3.3 Demonstrate operation of sprinkling pump’s associated remotely operated valves by running the pump with system isolation valves closed. Ensure overboard isolation valves are fully open and discharge pressure gauges indicate the design operating pressure.

9.3.4 Additional requirements for foam concentrate pump tests.

9.3.4.1 Foam concentrate pumps and seawater sprinkling pumps typically are tested simultaneously because they do not have individual controllers. In such instances, they both are started together at the master controller.

9.3.4.2 Ensure that the foam concentrate isolation valves to the foam proportioner are closed and tagged. Fill the foam concentrate tank with freshwater or foam concentrate to an adequate level to assure continuous suction. Align the pump to take suction from the tank and discharge back into the tank.

9.4 Zone control valve and hose reel unit operational demonstrations: Each zone control valve and hose reel unit shall be tested. (Warning—In addition to other precautions, the following steps are to be taken prior to demonstrations.)

9.4.1 Secure electrical power to the foam concentrate pumps. Ensure that appropriate remotely operated valves are closed and tagged. Set up the system for SEAWATER operation before initiating each OPEN command.

9.4.1.1 Ensure that all distribution piping downstream of the proportioners is aligned for normal operation.

9.4.1.2 Provide protection for all areas and equipment that may be water damaged by sprinkling or flooding incidental to these demonstrations.

9.4.1.3 Ensure that the vessel’s dewatering system(s) is fully functional and operating in areas where liquids might be discharged. (Warning—The amount of liquid on deck should be closely monitored during these demonstrations.)

9.4.2 Demonstration of hose reel units, if installed in the vessel.

9.4.2.1 Demonstrate the ability of each hose reel control START command to activate the sprinkling/foam system. Ensure the start-up sequence is accomplished by observing the seawater sprinkling pump master controller.

9.4.2.2 Verify seawater exits satisfactorily from the hose nozzle.

9.4.3 Demonstration of zone control valves. Demonstrate the ability of each zone control OPEN command to activate the sprinkling/foam system. Demonstrate the ability to secure each zone with CLOSE commands.

9.4.3.1 Ensure the start-up sequence is accomplished by observing the seawater sprinkling pump master controller. Observe operation of the remotely operated valve by moving from the fully closed to the fully open position and from fully open to the fully closed position.

9.4.3.2 Initiate local activation by initiating the OPEN command using each zone control local station. Close the remotely operated valve by initiating the CLOSE command.

9.4.3.3 Initiate remote activation with an OPEN command from DCC for each zone control valve. Close each remotely operating valve by initiating the CLOSE command.

9.4.3.4 Demonstrate operation of engine room bilge sprinkling and any other engine room foam systems from the fire control station. Initiate activation with an OPEN command; close the remotely operated valves by initiating the CLOSE command.

9.4.3.5 After the remotely operated valve for a particular zone is closed, secure the seawater sprinkling pump before the next demonstration of that zone or a different zone. Only one zone should be demonstrated at a time to verify proper coordination of the OPEN commands and activation of the seawater sprinkling pump.

9.5 Sprinkling/foam system operational test: A full operational test of the entire system shall be conducted before the vessel getting underway.

9.5.1 Prior to the test, complete the following steps.

9.5.1.1 Determine the two zones with the highest combined flow rate. If one or both of these zones are interior to the vessel, and two or more zones that are in weather will develop the
same or higher flow rates, the weather zones may be tested in lieu of two interior zones.

9.5.1.2 Determine the two foam maker nozzles that are hydraulically most remote from each foam proportioning station. Install test fittings (see 7.1.2) on those nozzles.

9.5.1.3 Isolate all zone control valves that will not be included in the test. (Warning—In addition to other precautions, provide protection for all areas and equipment that may be water damaged by sprinkling or flooding incidental to this test. “Socks” or other devices may be installed to contain the discharge from foam maker nozzles and directly route it to an area in which such discharge will be collected.) (Warning—The vessel’s dewatering system(s) must be fully functional before conduct of these demonstrations. The amount of liquid on deck should be closely monitored during these demonstrations.)

9.5.1.4 Verify that the seawater sprinkler pump sequential start time delays have been set. The primary foam proportioning station’s pump start sequence must have a shorter time delay than the secondary foam proportioning station’s pump.

9.5.1.5 Ensure that all foam concentrate tanks are filled with freshwater and that the tank levels are recorded. This step must accomplished for the demonstration of each foam proportioning station and must be repeated for the full system demonstration.

9.5.1.6 Ensure that educators, pumps, or other equipment needed to dewater the vessel during and after testing are in proper working order.

9.5.2 Demonstrate the ability of each foam proportioning station to be locally started and stopped using the seawater sprinkling pump master controller.

9.5.3 Demonstrate the ability of each foam proportioning station to be remotely started and stopped using commands from DCC.

9.5.3.1 In accordance with the design, demonstrate the proper mode is activated when the SEAWATER mode or FOAM mode is selected.

9.5.3.2 When a SEAWATER mode selector is provided, ensure that the foam proportioning station, when operated in the SEAWATER mode, defaults to the FOAM mode when it is secured.

9.5.4 Demonstrate the ability of each foam proportioning station to deliver fresh water (in lieu of using foam concentrate). Isolate other foam proportioning stations from the system during these demonstrations.

9.5.4.1 Locally start the pumps for a foam station in the SEAWATER mode. When good flow has been established to the selected zone, switch from the SEAWATER mode to the FOAM mode. Operate in the FOAM mode for 20 min and secure the Foam Proportioning Station.

9.5.4.2 Select the single zone requiring the highest flow rate (see 9.5.1.1). Determine the pressure reading at the most distant nozzle in that zone. Verify full flow from all nozzles in the selected zone.

9.5.4.3 Determine the pressure reading at the two hydraulically most distant nozzles from the foam proportioning station (see 9.5.1.2), regardless of the zone in which located. The minimum pressure shall not be less than that specified by the manufacturer of the foam maker nozzle for proper operation of the nozzle.

9.5.4.4 Excess water should be dumped overboard during the test of each foam proportioning station. Verify the design operating pressure is available at all times at the outlet main from the station.

9.5.5 Conduct a foam concentrate transfer demonstration. It should be conducted only after all tests requiring that freshwater be used in the foam concentrate tanks have been completed satisfactorily. This demonstration is to be conducted using foam concentrate only.

9.5.5.1 Remove all water from the foam concentrate tank, from the foam concentrate piping serving the proportioners, and from the foam transfer piping.

9.5.5.2 Demonstrate the operation of the hand transfer pump at each foam proportioning station. Using the hand transfer pump, transfer foam concentrate from a bulk shipping drum or barrel to the foam concentrate tank. Empty the drum.

9.5.5.3 Demonstrate the operation of each motor driven, foam concentrate transfer pump, if such pumps are installed in the vessel.

(a) (a) The operational test (see 9.3.2) should be completed before commencing this demonstration.

(b) (b) Conduct an operational demonstration of the pump by aligning it to take suction from the foam tank and discharge either back into the foam concentrate tank or to the concentrate tank at another foam proportioning station.

(c) (c) Fill the foam concentrate tank in one of the foam proportioning stations to at least half full. Demonstration transfer of concentrate by using the concentrate transfer pump to transfer all of the concentrate to another station.

9.5.6 Additional requirements for foam concentrate transfer pump tests, if installed in the vessel. (Warning—Ensure all appropriate remotely operated valves are closed and tagged to prevent contamination of the foam concentrate with freshwater or seawater.

9.5.6.1 Verify setting of the relief valve for the pump.

9.5.6.2 Fill the foam concentrate tank for the foam proportioning station with foam concentrate. Align the transfer pump to take suction from the tank and discharge either back to the tank or to another foam station. Commence an operational test of sufficient duration for the pump to have completely drained the tank twice, with the pump operating at its rated capacity. During the final portion of that test, transfer sufficient foam concentrate to another foam proportioning station to observe a change in level in that station’s tank.

9.5.6.3 Repeat the test for the transfer pump at each foam proportioning station until all stations have been tested.

9.6 Foam Concentrate Tests—A full operational test of the entire system shall be conducted with the vessel underway.

9.6.1 Before the full system operational test, complete the following steps.

9.6.1.1 Determine the two zones with the highest combined flow rate (see 9.5.1.1). Weather zones may be tested in lieu of interior zones.

9.6.1.2 Isolate all zone control valves that will not be included in the test. This should not be done until immediately
prior to the test to allow the zones to be used in case of actual emergency. (Warning—Provide protection for all areas and equipment that may be water damaged by sprinkling or flooding incidental to this test.)

9.6.1.3 Ensure that all foam concentrate tanks are filled with foam concentrate and that the tank levels are recorded.

9.6.2 Conduct the full operational test. This test will require the simultaneous operation of all foam proportioning stations, using foam concentrate. (Warning—The amount of liquid that accumulates on deck should be closely monitored during this test.)

9.6.2.1 If provided with a SEAWATER mode selector, start the seawater sprinkling pumps in the SEAWATER mode. When good flow has been established to all selected zones, switch from the SEAWATER mode to the FOAM mode.

(a) (a) Operate in the foam mode for at least 3 min after foam comes out of the nozzles.

(b) (b) Secure the foam proportioning station after samples have been taken.

(c) (c) Collect samples of the foam from the most and least remote locations in each zone. Samples are to be taken after 3 min of foam discharge.

(d) (d) Samples shall be analyzed to determine that the proper foam concentrate percentage is achieved at all locations throughout the test, as per design. Foam samples are to be tested for concentration in accordance with NFPA standard.

9.6.2.2 Excess water should be dumped overboard during the test of each foam proportioning station. Verify the design operating pressure is available at all times at the outlet main from the foam proportioning station.

9.6.2.3 Demonstrate the operation of each hose reel unit, if any are installed in the vessel. Accomplish the following when demonstrating of the hose reel(s):

(a) (a) Operate in the foam mode for 10 min.

(b) (b) Collect samples of the foam. Samples are to be taken after 5 and 10 min of operation. Samples shall be analyzed, in accordance with NFPA standard, to determine that the proper foam concentrate percentage is achieved throughout the test.

(c) (c) Drain the system when the test is complete.

10. Ordering Information

10.1 Ordering documentation for testing foam firefighting systems in accordance with this standard test method shall include the following information, as required, to describe the system adequately.

10.1.1 ASTM designation and year of issue,

10.1.2 Specifications for testing various components of the system,

10.1.3 Number of foam proportioning stations in the system,

10.1.4 Number and type of pumps in the system,

10.1.5 Number and service location of hose reel units in the system,

10.1.6 Prerequisite test requirements based on specifications invoked for components of the system, as described in 8.1,

10.1.7 Regulation accuracy required, if other than given in 3.5,

10.1.8 Pressure and capacity requirements, if specified by the owner, and

10.1.9 Foam system design USCG certification, if applicable.

11. Report

11.1 Report the following information:

11.1.1 Name of the industrial facility conducting the tests;

11.1.2 Date of tests and demonstrations;

11.1.3 Set of design drawings describing installation of the foam firefighting system and associated controls;

11.1.4 Nameplate data for each pump, motor, and controller;

11.1.5 Numerical data in tabular and graphic form (with identification of limits or pass/fail criteria):

11.1.5.1 Pump installation alignments;

11.1.5.2 Operational test data including: motor voltage, motor amperage, motor insulation resistance, revolutions per minute, pump suction and discharge pressures, and, any unusual conditions noted.

11.1.5.3 Identification of all hose reels demonstrated;

11.1.5.4 Identification of all sprinkling zones demonstrated for local and remote operation;

11.1.5.5 Time delays for foam proportioning station pumps;

11.1.5.6 Identification of foam proportioning stations demonstrated for local and remote operation;

11.1.5.7 Results of in-port testing using fresh water in lieu of foam concentrate: capacity of each foam concentrate tank, level of fresh water in each tank at start and conclusion of the demonstration for each zone, zones used in the demonstrations, pressure readings at most remote nozzles, and, any unusual conditions noted;

11.1.5.8 Results of underway testing using foam concentrate: seawater/foam measured ratios for each sample taken, zones used in the demonstrations, hose reels demonstrated, and any unusual conditions noted.

11.2 Report the following information for each failure to meet the accept/reject criteria of the test procedures:

11.2.1 Specific metrics of the failure,

11.2.2 Description of action(s) taken to correct the failure, and

11.2.3 Results of the retesting of all failed portions of the test procedure, including any applicable data of 11.1.

12. Precision and Bias

12.1 Precision—It is not possible to specify the precision of the procedure in this test method for fixed foam firefighting systems because results will vary from vessel to vessel or may vary for the same system on a single vessel owing to:

12.1.1 The test instrumentation and test setup will vary;

12.1.2 The designs of different systems will produce different values; and

12.1.3 The test procedures prepared by different industrial facilities that perform the testing over the life of the vessel.

12.2 Bias—No information can be presented on the bias of the procedure in this test method for fixed foam firefighting systems because of variances in the design of each vessel’s installation.
A1. TERMINOLOGY: GLOSSARY OF TERMS USED IN THIS TEST METHOD FOR FOAM FIREFIGHTING SYSTEMS

A1.1 Use of This Glossary of Terms:

A1.1.1 Test requirements associated with the terms described in this annex are for reference only. Specific test requirements are imposed using the ordering data for individual components.

A1.1.2 These terms are for reference only; components of a particular fixed fire fighting system may be identified by different nomenclature as part of the system design.

A1.2 Terms used in this test method for fixed foam firefighting systems.

A1.2.1 bias—the difference between the average measured test result and the accepted reference values (or accept/reject criteria); it measures in an inverse manner the accuracy of a test.

A1.2.2 bilge sprinkling system—a fixed foam sprinkling system in the bilges of a machinery space; includes distribution piping and foam maker sprinkling nozzles.

A1.2.3 control system—the electrical system used to monitor and control all of the equipment associated with the foam firefighting system. The control system includes the panels and consoles from which the foam fighting system can be operated and the interconnecting electrical signal cables or fiber optics.

A1.2.4 damage control console (DCC)—the central console in the control system at which the firefighting system can be monitored and controlled. Such console may be part of a fire detection system installation.

A1.2.5 foam concentrate—liquid solution that is mixed with seawater to make fire fighting foam.

A1.2.6 foam distribution system—the piping and valves that distribute seawater/foam solution from foam proportioning stations to nozzles or hose reels throughout the vessel, or both.

A1.2.7 fixed foam firefighting system—the tanks, pumps, interconnecting piping, foam distribution system piping and valves, local controls, foam maker sprinkling nozzles, and hose reels to provide seawater/foam solution to fight fires.

A1.2.8 foam maker sprinkling nozzle—a nozzle that mixes air with seawater/foam solution to sprinkle foam.

A1.2.9 foam proportioners—a unit that mixes foam concentrate and seawater in the proper proportions to make seawater/foam solution.

A1.2.10 foam transfer system—the pumps, piping, and valves that are used to transfer foam concentrate from one foam proportioning station to another.

A1.2.11 hose reel unit—a fixed unit that includes a reel and drum assembly from which a hose with foam maker nozzle can be deployed to allow portable direction of foam at the site of a fire. Some vessels may use a hose rack in a foam station cabinet such as one described by Specification F 1333 without a local proportioners, using seawater/foam solution from the foam distribution system in lieu of a local foam proportioners.

A1.2.12 local control panel—the panel that controls the valve operator for a zone control valve or hose reel unit isolation valve.

A1.2.13 master controller, seawater sprinkling pump—the motor controller for the seawater sprinkling pump; it also may be the motor controller for the foam concentrate pump.

A1.2.14 precision—a measurement concept that expresses the ability to generate test results that agree with each other in absolute magnitude.

A1.2.15 pressure, design operating—pressure used in design to determine the required minimum thickness and minimum mechanical properties (of the foam firefighting system).

A1.2.16 pressure, hydrostatic head—the static pressure at any point in the system created by a vertical column of liquid from that point to the highest point in system. Alternately, the pressure at any point in a tank created by vertical column of the liquid carried in that tank, from that point to the highest point in the tank vent.

A1.2.17 pressure, maximum system operating—the maximum pressure at which the foam firefighting system can be operated; typically, the highest pressure setting of any pressure relief device in the system.

A1.2.18 pump, foam concentrate—the pump that provides foam concentrate from the foam concentrate tank to the foam proportioners; they typically are Specification F 1510, Class A pumps sized with a capacity to provide foam simultaneously to the two largest zones in the vessel and should meet the test requirements of that specification.

A1.2.19 pump, foam concentrate transfer—a pump used to transfer foam concentrate solution from one foam proportioning station to another; they typically are Specification F 1510, Class A pumps sized with a relatively low capacity and should meet the test requirements of that specification.

A1.2.20 pump, hand transfer—a pump used to transfer foam concentrate from pails or barrels into foam concentrate tanks.

A1.2.21 pump, seawater sprinkling—a pump that takes sea suction and pumps seawater to the foam proportioners; they typically are Specification F 998, Class 5 pumps and should meet the test requirements of that specification.

A1.2.22 seawater/foam solution—a mixture of foam concentrate and seawater in proper proportions to make foam when discharged through a foam maker sprinkling nozzle or hose reel unit foam nozzle.

A1.2.23 station, fire control—the location used to monitor and control all of the equipment associated with the firefighting system in the engine room(s) and casing. The panels or console from which the engine room foam firefighting system can be operated and the interconnecting electrical signal cables or fiber optics are located at this station.
A1.2.24 station, foam proportioning—the location at which seawater/foam solution is generated and from which it is pumped to sprinkling zones, hose reels, and the engine room(s). This station typically includes the seawater sprinkling pump, foam concentrate tank, foam proportioning pump, foam proportioners, foam transfer pump, interconnecting piping and valves, and their controls.

A1.2.25 station foam transfer—a location which includes a pump concentrate transfer pump and control devices necessary to move foam concentrate.

A1.2.26 station, hose reel—a location used to monitor and control a foam hose reel unit.

A1.2.27 station, local control—a location at which an operator can monitor and control the foam sprinkling system in a zone.

A1.2.28 tank, foam concentrate—a tank for bulk stowage of foam concentrate; it is connected to the suction side of the foam concentrate pump.

A1.2.29 valve, bypass-overboard—a valve that allows the discharge of a pump in the fixed foam firefighting system to bypass the foam distribution system and be discharged overboard. Such valves also can function as relief valves which discharge overboard when the system pressure exceeds the valve’s set pressure.

A1.2.30 valve, foam proportioners seawater supply—a valve on the seawater inlet side of a foam proportioners that isolates it from its source of seawater, either the fire main or a seawater sprinkling pump.

A1.2.31 valve, hose reel—the quick opening valve that isolates a hose reel unit from the distribution main or risers for the seawater/foam solution.

A1.2.32 valve, remotely operated—a valve that uses an electric or hydraulic power-actuated operator to change its position. Remotely operated valves in the foam firefighting system can be positioned by either local or remote actuation and can be positioned using a manual operator.

A1.2.33 valve, pressure regulating—a valve that senses total pressure in the distribution piping downstream of the valve and adjusts the flow through the valve to maintain that pressure at a set level.

A1.2.34 valve, relief—a pressure-activated valve designed to relieve excessive pressure automatically. Such valves in the foam firefighting system can be integral to the system’s pumps or be a component of piping systems.

A1.2.35 valve, seawater bypass—the valve that bypasses the foam proportioners, allowing the foam firefighting system to distribute only seawater.

A1.2.36 valve, sprinkling pump seawater suction—the seawater on the seawater side of the seawater sprinkling pump.

A1.2.37 valve, zone control—the quick opening valve that isolates a zone from the distribution main or risers for the seawater/foam solution.

A1.2.38 zone—a section of the foam distribution system that includes all piping, valves, and sprinklers for a defined area of the ship.

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Standard Guide for Vessel-Related Technical Information for Use in Developing an Electronic Database and Ship Safety Record

This standard is issued under the fixed designation F 2001; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides a uniform format and definition of general vessel-related technical information, including ship safety data, to be used by ship owners and operators, at their option and to the extent that they consider beneficial to their operation. It is recognized that all of the data is already contained in various documents on the vessel, but normally not electronically and normally not in one location. The Ship Safety Record is designed to provide an industry-accepted common method of identifying, maintaining, and subsequently communicating the safety-related information needed for maritime operations. It is recognized that many of the data fields are not applicable for every vessel. Appendix X1 and Appendix X2 provide examples of how data elements in this guide may be used for a specific purpose, that is, the USCG’s Automated Identification System (AIS) and the Advance Notice of Arrival.

2. Referenced Documents

2.1 ASTM Standards:
F 1757 Guide for Digital Communication Protocols for Computerized Systems

2.2 IMO Documents:
The International Management Code for the Safe Operation of Ships and for Pollution Prevention— (The ISM Code) 1994
International Convention on Standards of Training, Certification and Watchkeeping for Seafarers— (STCW Convention) 1995
Convention on Facilitation of International Maritime Traffic, 1965, As Amended

2.3 US Coast Guard Documents:
33 CFR 160.207 Notice of Arrival: Vessels Bound for Ports or Places in the United States
33 CFR 160.211 Notice of Arrival: Vessels Carrying Certain Dangerous Cargo
2.4 Other Documents:
Paris Memorandum of Understanding (MOU) on Port State Control
Tokyo Memorandum of Understanding (MOU) on Port State Control
Acuerdo de Vina del Mar (MOU) Latin American Agreement
Memorandum of Understanding on Port State Control in the Caribbean Region (Caribbean MOU)
Memorandum of Understanding on Port State Control in the Mediterranean Region (Mediterranean MOU)
Indian Ocean Memorandum of Understanding on Port State Control (Indian Ocean MOU)
Memorandum of Understanding for the West and Central African Region (Abuja MOU)
Black Sea Memorandum of Understanding on Port State Control (Black Sea MOU)

3. Terminology

3.1 Abbreviations:
CAP—Condition Assessment Program
CFR—Code of Federal Regulations
ETA—estimated time of arrival
ETD—estimated time of departure
ILO—International Labor Organization
IMO—International Maritime Organization
IOPP—International Oil Pollution Prevention
ISM—International Management Code for the Safe Operation of Ships and for Pollution Prevention
ISM DOC—ISM Document of Compliance
ISM SMC—ISM Safety Management Certificate
MARPOL—International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 relating thereto
NLS—noxious liquid substance
NUC—not under command
OPA 90—U.S. Oil Pollution Act of 1990
RO RO—roll-on/roll-of vessel
SOLAS—Safety of Life at Sea Convention
STCW—International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1995
UTC—universal time coordinated

4. Significance and Use

4.1 The Ship Safety Record is an electronic database of information pertaining to a specific vessel including information related to the safe operation of the vessel and the safety of its crew and the environment. The data is grouped and organized under the following key categories: vessel particulars, vessel status, crew requirements, crew status, voyage specific data, record of inspection, record of incidents, and corrective actions.

4.2 The Ship Safety Record is created and maintained in each instance for the primary benefit of the owner, technical manager, or operator who is required through the implementation of the ISM Code to be cognizant of such information. The information in the database is at all times the property of the owner who will maintain and control the dissemination of any and all of the information. It is expected that operators will elect to make portions of their Ship Safety Record database available to other interested parties such as flag states, class societies, and port states. The Ship Safety Record should provide for the implementation of several levels of electronic database security as may be required by the vessel owner or operator. The data that becomes part of the Ship Safety Record can be thought of in a number of subsets:

4.2.1 Data that is not subject to change, including particulars of the vessel, and so forth.

4.2.2 Data that is subject to change but not normally by the ship’s crew.

4.2.3 Data that will be updated periodically either manually or as a result of updates to other computer systems or applications. This would include, as an example, cargo information, ballast conditions, the names/identification of crew members, and passenger details. This would also include information relative to internal inspections, maintenance records, internal audits, safety audits, and so forth.

4.3 Guides F 1756 and F 1757 may be used as the basis for implementation of a shipboard electronic database and ship safety record.

5. Vessel Particulars

5.1 Vessel Identification:
5.1.1 IMO number.
5.1.2 Vessel name.
5.1.3 Previous names.
5.1.4 Vessel type.
5.1.5 Vessel call sign.
5.1.6 Flag state.
5.1.7 Ship owner.
5.1.8 Ship operator (who is responsible for ISM compliance).
5.1.9 Company as defined in ISM Code.
5.1.10 Company contact information.
5.1.11 Current classification society.
5.1.12 Builder’s name.
5.1.13 Construction contract date.
5.1.14 Keel laying date.
5.1.15 Delivery date.
5.2 Vessel Certificates:
5.2.1 The actual list of certificates required for a vessel is a function of the vessel’s intended trade route, flag state, and international requirements.
5.2.1.1 Certificate of registry.
5.2.1.2 Safety equipment certificate.
5.2.1.3 Safety construction certificate(s).
5.2.1.4 Cargo ship safety certificate.
5.2.1.5 Passenger ship safety certificate.
5.2.1.6 Radio safety certificate.
5.2.1.7 Cargo ship radio telegraphy certificate.
5.2.1.8 Cargo ship radio telephony certificate.
5.2.1.9 SOLAS exemption certificate.
5.2.1.10 International load line certificate.
5.2.1.11 International load line exemption certificate.
5.2.1.12 Certificate of fitness (liquefied gases in bulk).
5.2.1.13 Certificate of fitness (chemicals in bulk).
5.2.1.14 Oil pollution certificate.
5.2.1.15 Delivery date.
5.2.1.16 Minimum Safe Manning Document.
5.2.1.17 ISM Safety Management Certificate.
5.2.1.18 ISM Document of Compliance.
5.2.1.19 Classification Certificates:
5.2.1.20 International Tonnage Certificate 1969.
5.2.1.21 National Certificates:
5.2.1.22 Panama Tonnage Certificate.
5.2.1.23 Suez Tonnage Certificate.
5.2.1.24 USCG Certificate of Inspection.

13 Technical information pertaining to Port State Control is included in a Memorandum of Understanding (MOU) for various regions worldwide as listed in 2.4.
5. Stability Approval Letter.
5.2.1.22 Ship’s radio station license.
5.2.1.23 Supplementary to Safety Steering Gear Certificate.
5.2.1.24 Certificate of Sanitary Construction.
5.2.1.25 Register of Cargo Gear.
5.2.1.26 Certificate of Documentation, unless 5.2.1.1.
5.2.1.27 Life Raft Certificates.
5.2.1.28 Certificates of Financial Responsibility (COFR).
5.2.1.29 ITOPF Membership Certificate.
5.2.1.30 Certificate of Deadweight.
5.2.1.31 U.S. Tonnage Certificate.
5.2.1.32 Certificate of Official Number.

5.3 Particulars of the Vessel’s Physical Characteristics:
5.3.1 (LOA) length overall (metres/feet).
5.3.2 (LBP) Length between perpendiculars (metres/feet).
5.3.3 Design draft (metres/feet).
5.3.4 Beam (metres/feet).
5.3.5 Keel to top of mast height (metres/feet).
5.3.6 (DWT) summer deadweight (metric tons).
5.3.7 (GRT) gross register tons (metric tons) (for Tankers may be reduced GRT in accordance with IMO Res. A388(x)).
5.3.8 GRT gross register tons U.S.
5.3.9 Displacement (metric tons).
5.3.10 Lightship weight (metric tons).
5.3.11 Molded depth at sea (metres/feet).
5.3.12 Description of steering gear.
5.3.13 Type of rudder.

5.4 Particulars of the Vessel Subdivision and Stability Data:
5.4.1 (VCG) light ship vertical center of gravity (metres/feet).
5.4.2 (LCG) light ship longitudinal center of gravity (metres/feet).
5.4.3 Cargo subdivision (number of holds or tanks).
5.4.4 Intact stability limitations (cargo conditions limiting vessel operation).
5.4.5 Damage stability criteria.
5.4.6 Minimum metacentric height; G.M.
5.4.7 Identification of shipboard trim and stability electronic program.

5.5 Particulars of the Vessels Machinery:
5.5.1 Main engine type.
5.5.2 Main engine manufacturer.
5.5.3 Main engine model.
5.5.4 Main engine rating.
5.5.5 Main engine fuel.
5.5.6 List of critical auxiliary machinery.

5.6 Particulars of the Vessel Safety System:
5.6.1 Number and size of fire pumps.
5.6.2 Number and type of fire extinguishers.
5.6.3 CO₂ system/ixed fire fighting systems.
5.6.4 Number and size of life boats.
5.6.5 Number and size of life rafts.
5.6.6 Automatic fire control system.

5.7 Particulars of the Vessel Navigation Systems:
5.7.1 Description of marine radar system.
5.7.2 Description of magnetic steering compass.
5.7.3 Description of gyro compass/repeater.
5.7.4 Description of rudder angle indicator.

5.8 Particulars of the Vessel Deck Machinery:
5.8.1 Number and capacity of anchors and anchor windlass.
5.8.2 Number and capacity of mooring winch.
5.8.3 Number and capacity of cargo and other lifting gear.
5.8.4 Cargo gear registry.
5.8.5 Number and capacity of hose handling crane.

5.9 Particulars of Cargo System:
5.9.1 Type of Cargo.
5.9.2 Vessels Cargo Handling Systems—Number and size of cargo pumps, description of piping system, cargo control system, manifolds, vessels dry cargo loading and unloading systems, cargo cranes, and so forth.
5.10 Vessel Communications Systems:
5.10.1 Radio equipment.
5.10.2 Shipboard Information Technology Platform (SITP); operating system.
5.10.3 Interior communications.
5.10.4 Satcom.
5.10.5 Cellular.
5.10.6 PC network.
5.11 Vessel Response Plan(s) (Can Include International and Locally Required Plans)—Notification contact names and numbers for the following:
5.11.1 Qualified individual.
5.11.2 Oil spill response organization.
5.11.3 Spill management team.
5.11.4 Salvage/fire fighting/lightering organization.
5.11.5 Electronic hull file location/custodian.
5.12 Incident/Accident Record (Dates of Each):
5.12.1 Pollution incident.
5.12.2 Grounding.
5.12.3 Collision.

6. Vessel Status
6.1 Status of Certificates—List the current status of each certificate as stated in 5.2. The actual list of certificates required for a vessel is a function of the vessel’s trade and will be determined by flag state and international requirements.
6.1.1 Certificate of Registry.
6.1.2 Safety Equipment Certificate.
6.1.3 Safety Construction Certificate(s).
6.1.4 Cargo Ship Safety Certificate.
6.1.5 Passenger Ship Safety Certificate.
6.1.6 Safety Radio Certificate.
6.1.7 Cargo Ship Radio Telegraphy Certificate.
6.1.8 Cargo Ship Radio Telephony Certificate.
6.1.9 SOLAS Exemption Certificate.
6.1.10 International Load Line Certificate.
6.1.11 International Load Line Exemption Certificate.
6.1.12 Certificate of Fitness (liquefied gases in bulk).
6.1.13 Certificate of Fitness (chemicals in bulk).
6.1.14 Oil Pollution Certificate.
6.1.14.1 IOPP Certificate/NLS Certificate and Form A Supplement (MARPOL) and Form B.
6.1.15 Hazardous & Noxious Substances Certificate.
6.1.16 Minimum Safe Manning Document.
6.1.17 ISM Safety Management Certificate.
6.1.18 ISM Document of Compliance.
6.1.19 Classification Certificates:
   6.1.19.1 Hull.
   6.1.19.2 Machinery.
   6.1.19.3 Automation.
6.1.21 National certificates:
   6.1.21.1 Panama Tonnage Certificate.
   6.1.21.2 Suez Tonnage Certificate.
6.1.21.3 USCG Certificate of Inspection.
6.1.21.5 Stability Approval Letter.
6.1.22 Ship’s Radio Station License.
6.1.23 Supplementary to Safety Steering Gear Certificate.
6.1.24 Certificate of Sanitary Construction.
6.1.25 Register of Cargo Gear.
6.1.27 Life Raft Certificates.
6.1.29 ITOPF Membership Certificate.
6.1.30 Certificate of Deadweight.
6.1.31 U.S. Tonnage Certificate.
6.1.32 Certificate of Official Number.
6.2 Status of Hull Structure:
   6.2.1 Local structural damage reported by crew as a result of routine on-board inspection.
   6.2.2 Temporary repairs to be completed.
   6.2.3 Outstanding items from last class survey report.
   6.2.4 Status of coatings.
   6.2.5 Status of cathodic protection system.
6.3 Status of Machinery: Inoperable Equipment, Repair Work Schedules, and So Forth:
   6.3.1 Main engine.
   6.3.2 Main and auxiliary boilers.
   6.3.3 Other auxiliaries.
6.3.4 Outstanding items from last Class Survey Report.
6.4 Status of Vessel Safety Systems:
   6.4.1 inoperable equipment.
   6.4.2 last operation of emergency generator.
6.4.3 Last operation of emergency fire pump.
6.4.4 Outstanding items from last Class Survey Report.
6.5 Status of Vessel Navigation Systems:
   6.5.1 Steering gear engines.
   6.5.2 Steering control system.
   6.5.3 Marine radar system.
   6.5.4 Magnetic steering compass.
   6.5.5 Gyro compass/Repeater.
   6.5.6 Rudder angle indicator.
   6.5.7 Outstanding items from last Class Survey Report.
6.5.8 Status of Global Positioning System (GPS) receiver(s)
6.6 Report on Fuel Quality—Report the following for each fuel on board:
   6.6.1 Density.
   6.6.2 Viscosity.
6.6.3 Pour point.
   6.6.4 Water content.
   6.6.5 Fuel stability.
   6.6.6 Abrasive particles.
   6.6.7 Salt water.
   6.6.8 Strong acidity.
   6.6.9 Sulfur content.
   6.7 Report on Lube Oil Quality:
   6.7.1 Change in viscosity.
   6.7.2 Presence of water.
   6.7.3 Strong acidity.
   6.7.4 Comparative viscosity.

7. Crew Requirements

7.1 Identification of Crew Positions Consistent with Safe Manning Requirements and Master List:
   7.1.1 Master.
   7.1.2 Officers in charge of a navigational watch.
   7.1.3 Chief mate.
   7.1.4 Officer in charge of a navigational watch; near—coastal voyage.
   7.1.5 Master—near—coastal voyage.
   7.1.6 Ratings forming part of a navigational watch.
   7.1.7 Officer in charge of engineering watch propulsion power (>750 kw).
   7.1.8 Chief engineer propulsion power (>3000 kw).
   7.1.9 Chief engineer propulsion power (750 to 3000 kw).
   7.1.10 Second engineer propulsion power (>3000 kw).
   7.1.11 Second engineer propulsion power (750 to 3000 kw).
   7.1.12 Ratings forming part of an engineering watch.
   7.1.13 Radio operator.
6.1.14 GMDSS qualified officers.
   7.1.15 Officers qualified to carry out cargo transfer operations.

7.2 Training Requirements—For each position and who qualified:
   7.2.1 Requirements for familiarity with company procedures.
   7.2.2 STCW training (in accordance with Section A-VI/1 and A-VZ as applicable):
   7.2.2.1 Tanker familiarization course—chemical tanker—liquified gas tanker.
   7.2.2.2 Personal survival techniques.
   7.2.2.3 Advanced fire fighting.
   7.2.2.4 Medical first aid.
   7.2.2.5 Personnel in charge of medical care.
   7.2.2.6 Personal safety and social responsibility.
   7.2.2.7 Ro-Ros (passenger ships).
   (1) Crowd management.
   (2) Crisis management.
   7.2.3 Survival craft and rescue boat training.
   7.2.4 Fast rescue boat training.
   7.2.5 Familiarization training.
   7.2.6 Listing of officers qualified to perform on-board training and on-board assessment of training.
8. Status of Crew and Persons Other Than Passengers on Board

8.1 Identification of Crew and Persons Other Than Passengers on Board:
8.1.1 Full name of each person.
8.1.2 Rank or rating.
8.1.3 Date and place of birth.
8.1.4 Muster list assignments.
8.1.5 Position as defined in 3.1 filled by each named crew member.
8.1.6 Date signed on.
8.1.7 Vacant positions from 7.1.

8.2 Certificate of Competency for Each Crew Member as Issued by Flag State of Vessel; (Issue Date, Validity):
8.2.1 Seafarer’s name.
8.2.2 Date of birth.
8.2.3 Nationality.
8.2.4 Sex.
8.2.5 Relevant document number.
8.2.6 Date of issue.
8.2.7 Date of expiry.
8.2.8 Last revalidation date.
8.2.9 Details of dispensation(s).
8.2.10 STCW certification of each licensed crew member.
8.2.10.1 STCW competency standard (for example, regulation II/I).
8.2.10.2 Title.
8.2.10.3 Function.
8.2.10.4 Endorsements.

8.3 Training Records—For each person on board other than passengers:
8.3.1 STCW training (as applicable to type of vessel and person with designated safety or pollution duties):
8.3.1.1 Tanker familiarization course.
8.3.1.2 Personal survival techniques.
8.3.1.3 Advanced fire fighting.
8.3.1.4 Medical first aid.
8.3.1.5 Personnel in charge of medical care.
8.3.1.6 Personal safety and social responsibility.
8.3.1.7 Ro-Ros (passenger ships).
8.3.2 Familiarization training.
8.3.3 Listing of personnel by position required to have on-board training record book.
8.3.4 Evidence of training in company procedures.
8.4 Medical Records for Each Crew Member:
8.4.1 Documented evidence of medical fitness for each crew member in accordance with ILO Convention No. 73.
8.4.2 Proof of drug/alcohol testing.

8.5 Log of Hours Worked (Compliance with OPA 90 STCW)—Hours worked each week for each crew member forming part of a navigational or engineering watch.
8.6 Required Drills Last Performed (Date and Time):
8.6.1 Fire drill/explosion.
8.6.2 Boat drill.
8.6.3 Rescue boat drill.
8.6.4 Man overboard drill.
8.6.5 Entering and leaving port equipment drills.
8.6.6 Abandon ship drill.
8.6.7 Enclosed space rescue drill.

9. Voyage Specific Data
9.1 Port of Departure (Last Port of Call):
9.1.1 Name of port, country.
9.1.2 Date and time of departure.
9.2 Destination Port (Next Port of Call):
9.2.1 Name of port, country.
9.2.2 Estimated time of arrival.
9.2.3 Facility name.
9.2.4 Loading/off loading.
9.2.5 Bunkering—Y/N.
9.2.6 Lightering—Y/N.
9.2.7 Agent.
9.3 Loading Pattern:
9.3.1 Tons of cargo in each liquid cargo tank and percent full.
9.3.2 Tons of fuel in each fuel tank and percent full.
9.3.3 Tons of bulk cargo in each cargo hold.
9.3.4 Tons of bulk cargo/containers stowed above deck.
9.3.5 Planned loading and off-loading sequence.
9.3.6 Type of cargo carried.
9.3.7 Location of each cargo carried.
9.4 Ballast Condition:
9.4.1 Tons of ballast in each ballast tank; percent full and location where ballast taken on.
9.4.2 Operating draft; (propeller immersion).
9.5 Passenger Details:
9.5.1 Name and nationality.
9.5.2 Assigned cabin.
9.5.3 Assigned lifeboat.
9.6 Critical Voyage Events (Other Than 5.12):
9.6.1 Off spec bunkers.
9.6.2 Heavy weather (deviation/damage).
9.6.3 Fire on board.
9.6.4 Cargo shifts.
9.6.5 Accident/personal injury.
9.6.6 Sickness.

10. Record of Inspection
10.1 Internal Inspections:
10.1.1 Inspections of hull by crew; date, findings, and action required.
10.1.2 Inspections of machinery by crew; date, findings, and action required.
10.2 Audit Reports:
10.2.1 Shipboard audit deficiencies and corrective action taken.
10.2.2 Internal ISM audits (company management and shipboard).
10.2.3 External ICM audits (company management and shipboard).
10.2.4 Other external audit reports (company management and shipboard).
10.3 Classification Survey Records:
10.3.1 Annual hull survey.
10.3.2 Annual machinery survey.
10.3.3 Intermediate survey hull.
10.3.4 Intermediate survey machinery.
10.3.5 Special survey hull.
10.3.6 Special survey machinery.
10.4 Flag State Inspections:
10.4.1 Safety construction inspection.
10.4.2 Safety equipment inspection.
10.4.3 IOPP inspection.
10.4.4 Safety radio inspection.
10.4.5 Load line inspection.
10.5 Port State Inspections:
10.5.1 Control number.
10.5.2 Annual.
10.5.3 Reexamination.
10.5.4 Inspection for Certificate of Compliance.
10.5.5 Ballast tank examination.
10.6 CAPs and Vettings—For each type of survey, list the surveyor, date, and deficiency.
10.7 Certifying Authority ISM Audits of Operations Procedures (Dates Due/Completed, for Each):
10.7.1 Annual office audit (SMC).
10.7.2 Intermediate ship audit (DOC).
10.7.3 DOC renewal audit.

11. Record of Incidents
11.1 Port State Restrictions:
11.1.1 Prevented from entering port.
11.1.2 Cargo operation delayed pending examination.
11.1.3 Fines imposed.
11.1.4 Vessel arrested.
11.2 Unscheduled Off-Hire:
11.2.1 Equipment failure at sea.
11.2.2 Delays for ship assist/rescue.
11.2.3 Berth availability.
11.2.4 Cargo transfer restrictions.
11.2.5 External interference, for example, weather delays, acts of war, piracy.
11.3 Other Reportable Incidents:
11.3.1 Loss of propulsion.
11.3.2 Loss of electrical power.
11.3.3 Loss of steering.
11.3.4 Oil spill on-board.
11.3.5 Navigational error.
11.3.6 Near-miss incidents.

12. Corrective Actions
12.1 Scheduled Critical Maintenance:
12.1.1 By ship’s crew.
12.1.2 By shore crew.
12.1.3 By dry docking.
12.2 Awaiting Critical Equipment:
12.2.1 Equipment for vital ship’s systems.
12.2.2 Equipment for personal safety.
12.2.3 Equipment for shipboard safety systems.
12.2.4 Equipment for navigational systems.
12.3 Critical Documentation Needed:
12.3.1 Navigational information (charts, and so forth).
12.3.2 Vendor maintenance and repair manuals.
12.3.3 Required emergency notification information.
12.3.4 Updates on classification/statutory status reports.
12.4 Deficiency Log—Deficiencies not reported under other systems.

13. Keywords
13.1 Advance Notice of Arrival; ISM Code; maritime operations; port state control; ship electronic database; ship safety record

ANNEX
(Mandatory Information)

A1. REFERENCED STANDARDS

Standards referenced in this guide are available for purchase as follows:
ISO and IEC Standards from
American National Standards Institute (ANSI)
11 W. 42nd St.
New York, NY 10036
Tel. 212-642-3946
Fax 212-302-1286
IEEE Standards form
Institute of Electrical and Electronic Engineers
PO Box 1331
Piscataway, NJ 08855-1331
Tel 800-678-4333 (U.S. and Canada)
Tel 908-981-1393 (outside U.S. and Canada)
Fax 908-981-9667
ASTM Standards from
American Society for Testing and Materials
100 Barr Harbor Dr.
PO Box C700
West Conshohocken, PA 19428-2959
NMEA Standards from
National Marine Electronics Association
PO Box 3435
New Bern, NC 28564-3435
IMO Publications from
International Maritime Organization
4 Albert Embankment
London, U.K. SE1 7SR
United States Coast Guard Documents
Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402
APPENDIXES
(Nonmandatory Information)

X1. UNITED STATES COAST GUARD

X1.1 Automatic Identification System (AIS) View

X1.1.1 Mobile marine station identification (MMSI).
X1.1.2 Call sign, 5.1.5.
X1.1.3 Name, 5.1.2.
X1.1.4 Dimensions of ship, 5.3.1-5.3.5.
X1.1.5 Type of ship, 5.1.4.
X1.1.6 Position of fixing antenna on the ship.
X1.1.7 Ship’s position with accuracy indication.
X1.1.8 Time in UTC.
X1.1.9 Course over ground.
X1.1.10 Speed over ground.
X1.1.11 Heading.
X1.1.12 Navigational Status (for example, NUC, at anchor, and so forth)
X1.1.13 Rate of turn (where available).
X1.1.14 Angle of heel (where available).
X1.1.15 Pitch and roll (where available).
X1.1.16 Ship’s draught, 9.4.2.
X1.1.17 Hazardous cargo (type), 9.3.6.
X1.1.18 Destination, 9.2.1.
X1.1.19 ETA, 9.2.2.

X1.1.20 Short safety-related messages.

X1.2 Ship Damage Reporting to Nearest Coastal State

X1.2.1 Risk of pollution report, 5.12.1.

X1.3 Personnel Casualty Reporting to Company

X1.3.1 Report of death, injury, and serious illness, 9.6.5.
X1.3.2 Nature and cause of injury.

X1.4 Casualty Reporting to Company (Initial and Final Report for each)

X1.4.1 Collision, structural damage, grounding, stranding, fire, and explosion, 5.12.2 and 5.12.3.
X1.4.2 Machinery breakdown, damage to machinery space, and flooding, 6.3.1-6.3.3.
X1.4.3 Damage/loss to cargo.

X1.5 Oil Spill and Pollution

X1.5.1 Report to local government agencies,
X1.5.2 company,
X1.5.3 designated qualified individual, and
X1.5.4 Oil Spill Response Agency.

X2. USCG ADVANCE NOTICE OF ARRIVAL - PORT STATE CONTROL (PSC)

X2.1 The United States Coast Guard’s Advance Notice of Arrival for vessels bound for ports or places in the United States, in accordance with 33 CFR 160.207, shall include the following:

X2.1.1 The owner, agent, master, operator, or person in charge of a vessel (except a barge bound for a port or place in the United States) shall report the following at least 24 h before entering the port or place of destination to the captain of the port of destination.

X2.1.2 The Ship Safety Record (SSR) Reference Group is provided as follows to demonstrate that for vessels provided with an electronic Ship Safety Record, all the data in the Notice of Arrival has already been captured.

<table>
<thead>
<tr>
<th>Item</th>
<th>Main Document Reference Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel name</td>
<td>5.1.2</td>
</tr>
<tr>
<td>Name of registered owner</td>
<td>5.1.7</td>
</tr>
<tr>
<td>Name of operator</td>
<td>5.1.8</td>
</tr>
<tr>
<td>Flag</td>
<td>5.1.6</td>
</tr>
<tr>
<td>Call sign</td>
<td>5.1.5</td>
</tr>
<tr>
<td>IMO number</td>
<td>5.1.1</td>
</tr>
<tr>
<td>Name of classification society</td>
<td>5.1.11</td>
</tr>
<tr>
<td>Type of vessel</td>
<td>5.1.4</td>
</tr>
<tr>
<td>Name and telephone number of 24-h point of contact</td>
<td>5.11.1</td>
</tr>
<tr>
<td>SMC information</td>
<td>6.1.17 &amp; 6.1.18</td>
</tr>
<tr>
<td>ETA Date/Time</td>
<td>9.2.2</td>
</tr>
<tr>
<td>ETD Date/Time</td>
<td>9.1.2</td>
</tr>
<tr>
<td>Last port of call</td>
<td>9.1.1</td>
</tr>
<tr>
<td>Next port of call</td>
<td>9.2.1</td>
</tr>
<tr>
<td>Type of cargo</td>
<td>9.3.6</td>
</tr>
<tr>
<td>Loading/off-load</td>
<td>9.2.4</td>
</tr>
<tr>
<td>Facility name</td>
<td>9.2.3</td>
</tr>
<tr>
<td>Bunkering</td>
<td>9.2.5</td>
</tr>
<tr>
<td>Lightering</td>
<td>9.2.6</td>
</tr>
<tr>
<td>Agent</td>
<td>9.2.7</td>
</tr>
</tbody>
</table>

X2.1.3 In accordance with 33 CFR 160.211, for vessels carrying certain dangerous cargo, in addition to the preceding, the Advance Notice of Arrival is to report the location of the vessel and the following:

<table>
<thead>
<tr>
<th>Item</th>
<th>Main Document Reference Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name and tons of each dangerous cargo and tank stowage</td>
<td>9.3.1</td>
</tr>
<tr>
<td>Operational condition of navigation equipment</td>
<td>6.5.3-6.5.6</td>
</tr>
</tbody>
</table>
1. Scope

1.1 This specification covers the pipe materials and dimensions for producing non-reinforced extruded tee connections manufactured by mechanical forming processes. The term “extruded tee connection” applies to butt-weld or socket-weld connections. This specification refers to the forming process that leads to welding or brazing.

1.2 The non-reinforced extruded pipe tee connection is an alternative to the tee fittings, nozzle, and other welded connections.

1.3 The non-reinforced extruded pipe tee connection has been widely used for systems in the marine, process piping, food, pharmaceutical, and similar industries.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The extruded tee connection will be welded in accordance with Specification F 722. Brazing of tee connections will be in accordance with ANSI B31.5.

2. Referenced Documents

2.1 ASTM Standards:
A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless\(^2\)
A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service\(^2\)
A 135 Specification for Electric-Resistance-Welded Steel Pipe\(^2\)
A 139 Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)\(^3\)
A 161 Specification for Seamless Low-Carbon and Carbon-Molybdenum Steel Still Tubes for Refinery Service\(^2\)
A 178/A 178M Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes\(^2\)
A 199/A 199M Standard Specification for Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes\(^3\)
A 200 Specification for Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service\(^2\)
A 209/A 209M Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes\(^2\)
A 210/A 210M Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes\(^2\)
A 250/A 250M Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes\(^2\)
A 252 Specification for Welded and Seamless Steel Pipe Piles\(^2\)
A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steels Pipes\(^3\)
A 333/A 333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service\(^2\)
A 334/A 334M Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service\(^2\)
A 500 Specification for Cold-Formed Welded and Seamless Carbon-Steel Structural Tubing in Rounds and Shapes\(^2\)
A 512 Specification for Cold-Drawn Butt Weld Carbon-Steel Mechanical Tubing\(^2\)
A 519 Specification for Seamless Carbon and Alloy Steel Mechanical Tubing\(^2\)
A 587 Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry\(^2\)
A 589 Specification for Seamless and Welded Carbon-Steel Water-Well Pipe\(^2\)
A 672 Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures\(^2\)
B 88 Specification for Seamless Copper Water Tube\(^4\)
B 88M Specification for Seamless Copper Water Tube [Metric]\(^4\)
B 280 Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service\(^4\)
B 337 Specification for Seamless and Welded Titanium and

\(^{1}\) This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.
\(^{2}\) Annual Book of ASTM Standards, Vol 01.01.
\(^{4}\) Annual Book of ASTM Standards, Vol 02.01.
Titanium Alloy Pipe
B 338 Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
B 466/B 466M Specification for Seamless Copper-Nickel Pipe and Tube
B 467 Specification for Welded Copper-Nickel Pipe
F 722 Specification for Welded Joints for Shipboard Piping Systems
2.2  ANSI Standards:
B 31.1 Power Piping
B 31.3 Chemical Plant and Petroleum Refining Piping
B 31.5 Refrigeration Piping
B 36.10M Welded and Seamless Wrought Steel Pipe
2.3 ISO Standard:
ISO-4200 Plain End Steel Tubes, Welded and Seamless—General Table of Dimensions and Masses Per Unit Length

3. Terminology
3.1 Definitions:
3.1.1 extruded tee connection—the tee outlet formed from the run pipe, subsequently welded or brazed to make a connection (see Fig. 1), also known in industry as a branch connection, mechanically formed tee connection, and also extruded outlet.
3.2 tee ratio—the ratio of the formed tee connection diameter, divided by the run pipe diameter as follows:

\[ \frac{D_t}{D_r} = \text{tee ratio} \]  

4. Dimensions and Tolerances
4.1 For welded connections, the dimensions and tolerances of the extruded tee connection shall be within the tolerances of the mating pipe in accordance with Specification F 722, as applicable to ANSI B31.1 and B31.3.

4.2 For braze connections, the dimensions and tolerances of the extruded tee connection shall be within the tolerances of the mating pipe in accordance with Specification F 722, as applicable to B31.5.

5. Run Pipe Materials and Limitations
5.1 Table 1 contains a list of materials that have been found to have acceptable forming qualities to produce extruded tee connections:

<table>
<thead>
<tr>
<th>Table 1 Materials That Have Acceptable Forming Qualities To Produce Extruded Tee Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Copper nickel</td>
</tr>
<tr>
<td>Titanium</td>
</tr>
<tr>
<td>Steel</td>
</tr>
<tr>
<td>Stainless steel</td>
</tr>
</tbody>
</table>

8 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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FIG. 1 Extruded Tee Connection

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\[ \text{FIG. 1 Extruded Tee Connection} \]
The material shall be in a normalized or fully annealed condition before cold forming the extruded tee.

The steel shall be hot formed in the temperature range from 850 to 1000°C (from 1562 to 1832°F). Under these conditions, no subsequent stress relieving is required.

6. Finish, Appearance, and Repairs

6.1 The extruded tee connection shall be free from burrs and cracks, which would affect the suitability for the intended service.

6.2 Pipe/tube repairs are permitted in accordance with the applicable ASTM specification.

7. Run by Tee Connection Sizes (See Figs. 2-13)

7.1 The pipe/tube figures (Figs. 2-13) represent a matrix of the process capabilities, reflecting the extruded tee connections that can be formed from the main pipe/tube diameters and wall thicknesses.

7.2 The pipe and tube sizes and dimensions referred to in Figs. 2-13 are per ANSI B36.10M and ISO 4200. Interpolation is allowable for sizes not covered.

7.3 The limitations are based on current technology and are subject to amendment to equipment or process developments, or both.

8. Allowable Pressures and Temperatures

8.1 The allowable pressures and temperatures shall be in accordance with ANSI B31.1, B31.3, and B31.5 as applicable.

9. Keywords

9.1 extruded outlet; mechanically formed tee connections; outlets; tee connections
**NOTE 1**—Limitation shown in applicable box: \( K = K \) copper, \( L = L \) copper, and \( M = M \) copper.

**NOTE 2**—Minimum wall copper is Class DWV.

**NOTE 3**—Dimensions are nominal copper tube size (CTS) with actual OD in parentheses.

**NOTE 4**—All dimensions are in inches.

**FIG. 2 Extruded Tee Connection Sizes and Wall Thickness for Copper Tube (Inches)**

| B (Nominal) | Actual | \( \frac{1}{4} \) (0.08") | \( \frac{3}{8} \) (0.37") | \( \frac{1}{2} \) (0.5") | \( \frac{5}{8} \) (0.63") | \( \frac{3}{4} \) (0.75") | 1 (1.0") | 1 1/4 (1.38") | 1 1/2 (1.5") | 2 (2.0") | 2 1/2 (2.5") | 3 (3.0") | 4 (4.0") | 5 (5.0") | 6 (6.0") | 8 (8.0") | 10 (10.0") | 12 (11.0") |
|------------|--------|----------------|----------------|----------------|----------------|----------------|--------|--------------|-------------|--------|-------------|-----------|--------|---------|---------|---------|--------|----------|----------|
| 1/4 (0.08") | \( L \) | 0.04 | K | 0.09 |          |          |          |          |              |          |          |              |          |        |
| 1/2 (0.5")  | \( L \) | 0.05 | K | 0.06 | K | 0.09 | K | 0.10 |          |          |          |              |          |        |
| 3/4 (0.75") | \( L \) | 0.07 | K | 0.09 | K | 0.10 | K | 0.11 |          |          |          |              |          |        |
| 1 (1.0")    | \( L \) | 0.10 | K | 0.10 | K | 0.10 | K | 0.11 |          |          |          |              |          |        |
| 1 1/4 (1.38") | \( L \) | 0.12 | K | 0.11 | K | 0.12 | K | 0.12 |          |          |          |              |          |        |
| 1 1/2 (1.5") | \( L \) | 0.15 | K | 0.12 | K | 0.12 | K | 0.13 |          |          |          |              |          |        |
| 2 (2.0")    | \( L \) | 0.17 | K | 0.13 | K | 0.13 | K | 0.13 |          |          |          |              |          |        |
| 2 1/2 (2.5") | \( L \) | 0.20 | K | 0.14 | K | 0.14 | K | 0.14 |          |          |          |              |          |        |
| 3 (3.0")    | \( L \) | 0.23 | K | 0.15 | K | 0.15 | K | 0.15 |          |          |          |              |          |        |
| 4 (4.0")    | \( L \) | 0.27 | K | 0.16 | K | 0.16 | K | 0.16 |          |          |          |              |          |        |
| 5 (5.0")    | \( L \) | 0.30 | K | 0.17 | K | 0.17 | K | 0.17 |          |          |          |              |          |        |
| 6 (6.0")    | \( L \) | 0.33 | K | 0.18 | K | 0.18 | K | 0.18 |          |          |          |              |          |        |
| 8 (8.0")    | \( L \) | 0.40 | K | 0.20 | K | 0.20 | K | 0.20 |          |          |          |              |          |        |
| 10 (10.0")  | \( L \) | 0.45 | K | 0.22 | K | 0.22 | K | 0.22 |          |          |          |              |          |        |
| 12 (11.0")  | \( L \) | 0.50 | K | 0.24 | K | 0.24 | K | 0.24 |          |          |          |              |          |        |

Nearest copper designation to maximum wall

**Max wall (in)**

Note: 1—Limitation shown in applicable box: \( K = K \) copper, \( L = L \) copper, and \( M = M \) copper.
Note: 2—Minimum wall copper is Class DWV.
Note: 3—Dimensions are nominal copper tube size (CTS) with actual OD in parentheses.
Note: 4—All dimensions are in inches.
**NOTE 1**—All sizes are shown in millimetres (mm).

**FIG. 3** Extruded Tree Connection Sizes and Wall Thickness for Copper Nickel Pipe—Metric (mm)
## Extruded Tee Connection Sizes and Wall Thickness for Copper and Copper Nickel Pipe—NPS

<table>
<thead>
<tr>
<th>PIPE (NPS)</th>
<th>3/8</th>
<th>1/2</th>
<th>1</th>
<th>1 1/4</th>
<th>1 3/4</th>
<th>2</th>
<th>2 1/2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>.065</td>
<td>.025</td>
<td>3/4</td>
<td>.080</td>
<td>.080</td>
<td>.025</td>
<td>.040</td>
<td>.040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIPE 1 1/2</td>
<td>.083</td>
<td>.090</td>
<td>1</td>
<td>.090</td>
<td>.090</td>
<td>.109</td>
<td>.025</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td></td>
</tr>
<tr>
<td>PIPE 1 1/4</td>
<td>.083</td>
<td>.090</td>
<td>1 1/4</td>
<td>.120</td>
<td>.114</td>
<td>.114</td>
<td>.154</td>
<td>.025</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td></td>
</tr>
<tr>
<td>PIPE 2</td>
<td>.083</td>
<td>.090</td>
<td>1 1/2</td>
<td>.120</td>
<td>.114</td>
<td>.114</td>
<td>.154</td>
<td>.025</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td></td>
</tr>
<tr>
<td>PIPE 2 1/2</td>
<td>.083</td>
<td>.090</td>
<td>2</td>
<td>.120</td>
<td>.120</td>
<td>.120</td>
<td>.203</td>
<td>.203</td>
<td>.025</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
<td>.040</td>
</tr>
<tr>
<td>PIPE 3</td>
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**Notes:**
- Max wall (in)
- Min wall (in)
### Fig. 5 Extruded Tee Connection Sizes and Wall Thickness for Titanium Tube—Metric (mm)

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**Note 1:** All sizes are shown in millimetres (mm).
**FIG. 6 Extruded Tee Connection Sizes and Wall Thickness for Titanium Pipe— NPS**

Note: 1—Limitations shown for applicable schedules: S = standard wall, 40 = Sch 40, 20 = Sch 20, 10 = Sch 10, 30 = Sch 30, and 5 = Sch 5.
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**Note 1**—All dimensions are in inches.

**FIG. 7** Extruded Tee Connection Sizes and Wall Thickness for Titanium Tube (Inches)
**Note 1**—All sizes are shown in millimetres (mm).

**FIG. 8 Extruded Tee Connection Sizes and Wall Thickness for Steel—Metric (mm)**

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Note: 1—Limitations shown for applicable schedules: 5 = Sch 5 S, 10 = Sch 10, 20 = Sch 20, 30 = Sch 30, S = standard wall, and 40 = Sch 40.

FIG. 9 Extruded Tee Connection Sizes and Wall Thickness for Steel Pipe—NPS
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**Note 1**—Inch sizes for steel tube currently available through 12 in.

**Note 2**—All dimensions are in inches.
### FIG. 11 Extruded Tee Connection Sizes and Wall Thickness for Stainless Steel Pipe—Metric (mm)

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**Note:** All sizes are shown in millimetres (mm).
**FIG. 12 Extruded Tee Connection Sizes and Wall Thickness for Stainless Steel Pipe—NPS**

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**Note 1:** Limitations shown for applicable schedule: 5 = Sch 5, 10 = Sch 10, 10S = Sch 10S, 20 = Sch 20, 30 = Sch 30, S = standard wall, and 40 = Sch 40.
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**Note 1:** Inch sizes for stainless steel tube currently available through 12 in.

**Note 2:** All dimensions are in inches.

**FIG. 13 Extruded Tee Connection Sizes and Wall Thickness for Stainless Steel Tube (Inches)**
Standard Specification for Lap Joint Flange Pipe End Applications

This specification covers the pipe material and wall thickness applicable to lap joint flange pipe ends, manufactured by a mechanical forming process.

1. Scope

1.1 This specification covers the pipe material and wall thickness applicable to lap joint flange pipe ends, manufactured by a mechanical forming process.

1.2 The lap joint flange connection has been widely used for low-pressure systems in the marine, process piping, and similar industries.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service

A 135 Specification for Electric-Resistance-Welded Steel Pipe

A 139 Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)

A 161 Specification for Seamless Low-Carbon and Carbon-Molybdenum Steel Still Tubes for Refinery Service

A 178/A 178M Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes

A 199/A 199M Specification for Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes

A 200 Specification for Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service

A 209/A209M Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

A 210/A 210M Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes

A 250/A 250M Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes

A 252 Specification for Welded and Seamless Steel Pipe Piles

A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes

A 333/A 333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service

A 334/A 334M Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service

A 500 Specification for Cold-Formed Welded and Seamless Carbon-Steel Structural Tubing in Rounds and Shapes

A 512 Specification for Cold-Drawn Butt weld Carbon-Steel Mechanical Tubing

A 519 Specification for Seamless Carbon and Alloy Steel Mechanical Tubing

A 587 Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry

A 589 Specification for Seamless and Welded Carbon-Steel Water-Well Pipe

A 672 Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures

B 42 Specification for Seamless Copper Pipe, Standard Sizes

B 88 Specification for Seamless Copper Water Tube

B 88M Specification for Seamless Copper Water Tube [Metric]

B 280 Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service

B 337 Specification for Seamless and Welded Titanium and Titanium Alloy Pipe

B 338 Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers

B 466/B 466M Specification for Seamless Copper-Nickel Pipe and Tube

B 467 Specification for Welded Copper-Nickel Pipe

2.2 ANSI Standards:

B31.1 Power Piping

B31.3 Chemical Plant and Petroleum Refining Piping

1 This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery and Piping Systems.


4 Annual Book of ASTM Standards, Vol 02.01.


7 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
B16.5 Pipe Flanges and Flanged Fittings

B16.9 Factory-Made Wrought Steel Butt-Welding Fittings

B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings: Class 150, 300, 400, 600, 900, 1500, and 2500

B16.42 Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300

2.3 ISO Standard:

ISO-7005-1 Metallic Flanges Part 1: Steel Flanges

ISO-7005-2 Metallic Flanges Part 2: Cast Iron Flanges

ISO-7005-3 Metallic Flanges Part 3: Copper Alloy and Composite Flanges

3. Terminology

3.1 back-up flange—the flange used to back up the lap joint to facilitate the pipe connection, also known in industry as loose, slip, plate, or spin flange.

3.2 convoluted flange—a back-up flange designed with a variable cross section to provide the material in the stress-related zones.

3.3 lap joint end—the formed pipe end to accommodate the back-up flange, commonly referred to as a Van Stone flange (see Fig. 1).

4. Dimensions and Tolerances

4.1 The lap joint end outside diameter shall be formed to the raised face flange diameter as covered under ISO Standard 7005-1, 7005-2, 7005-3, and ANSI B16.9 Table 7, Dim. G.

4.2 The back-up flange dimensions are covered under ANSI Standards B16.5, B16.24, and B16.42, and ISO Standards 7005-1, 7005-2, and 7005-3.

5. Fabrication

5.1 The formed lap joint end may have a smooth or serrated face.

5.2 The back-up flange may be a different material from the lap joint end pipe as long as it conforms to the applicable piping system codes or standards.

5.3 Convoluted back-up flanges may be used if they comply with the applicable piping system codes or standards.

6. Pipe Materials and Limitations

6.1 Table 1 contains a list of materials that have been found to have acceptable forming qualities to produce a lap joint end.

7. Finish, Appearance and Repairs

7.1 The lap joint flange pipe connection shall be produced in accordance with accepted shop practices and shall be free from burrs and cracks, which would affect the suitability for the intended service.

7.2 Pipe/tube repairs are permitted in accordance with the applicable ASTM specification.

---

**TABLE 1 Materials Having Acceptable Forming Qualities to Produce a Lap Joint End**

<table>
<thead>
<tr>
<th>Material</th>
<th>ASTM Material Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>B 88</td>
</tr>
<tr>
<td>Copper</td>
<td>B 280</td>
</tr>
<tr>
<td>Copper nickel</td>
<td>B 466/B 466M</td>
</tr>
<tr>
<td>Copper nickel</td>
<td>B 467</td>
</tr>
<tr>
<td>Titanium</td>
<td>B 337 Grades 1 and 2</td>
</tr>
<tr>
<td>Titanium</td>
<td>B 338 Grades 1 and 2</td>
</tr>
<tr>
<td>Steel</td>
<td>A 53</td>
</tr>
<tr>
<td>Steel</td>
<td>A 135</td>
</tr>
<tr>
<td>Steel</td>
<td>A 161 low carbon</td>
</tr>
<tr>
<td>Steel</td>
<td>A 199/A 199M Grade T11</td>
</tr>
<tr>
<td>Steel</td>
<td>A 209/A 209M Grade T1</td>
</tr>
<tr>
<td>Steel</td>
<td>A 250 Grade T16</td>
</tr>
<tr>
<td>Steel</td>
<td>A 333/A 333M Grade 1</td>
</tr>
<tr>
<td>Steel</td>
<td>A 500 Grade A</td>
</tr>
<tr>
<td>Steel</td>
<td>A 519 Grade 1010</td>
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<tr>
<td>Steel</td>
<td>A 589 Grade A</td>
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<tr>
<td>Steel</td>
<td>A 106 Grade B</td>
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<tr>
<td>Steel</td>
<td>A 139 Grade A</td>
</tr>
<tr>
<td>Steel</td>
<td>A 178/A 178M</td>
</tr>
<tr>
<td>Steel</td>
<td>A 200 Grade T36</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 304</td>
</tr>
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<td>A 312/A 312M TP 304L</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 309S</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 310S</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 316</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 316L</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 317</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 321</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A 312/A 312M TP 347</td>
</tr>
</tbody>
</table>

---

Fine print:

a Titanium run pipe must be commercially pure (99.1 %).

b Steel shall be hot formed in the temperature range from 850 to 1000°C (from 1562 to 1832°F). Under these conditions, no subsequent stress relieving is required.
8. Dimensional Limitations (see Tables 2-4)

8.1 Interpolation is allowable for sizes not covered.
8.2 The limitations are based on current technology subject to amendment to equipment or process developments, or both.

### TABLE 2 Lap Joint Flange—Dimensional Limitations for Tube (SI Units)

**NOTE 1**—Key: 10 ≤ maximum wall in mm. 2 ≤ minimum wall in mm.

<table>
<thead>
<tr>
<th>Tube Diameter, mm</th>
<th>Carbon Steel</th>
<th>Stainless Steel</th>
<th>Copper Nickel</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.3</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>2.4</td>
</tr>
<tr>
<td>26.9</td>
<td>3.7</td>
<td>3.5</td>
<td>4.0</td>
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<tr>
<td>33.7</td>
<td>4.0</td>
<td>3.7</td>
<td>4.5</td>
<td>3.1</td>
</tr>
<tr>
<td>42.4</td>
<td>5.5</td>
<td>4.7</td>
<td>5.5</td>
<td>3.1</td>
</tr>
<tr>
<td>48.3</td>
<td>6.2</td>
<td>5.0</td>
<td>6.0</td>
<td>3.1</td>
</tr>
<tr>
<td>60.3</td>
<td>7.0</td>
<td>5.0</td>
<td>6.0</td>
<td>3.1</td>
</tr>
<tr>
<td>76.1</td>
<td>8.0</td>
<td>5.8</td>
<td>6.0</td>
<td>3.4</td>
</tr>
<tr>
<td>88.9</td>
<td>8.8</td>
<td>5.8</td>
<td>6.0</td>
<td>3.4</td>
</tr>
<tr>
<td>114.3</td>
<td>9.5</td>
<td>5.8</td>
<td>6.0</td>
<td>3.4</td>
</tr>
<tr>
<td>139.7</td>
<td>9.5</td>
<td>5.8</td>
<td>6.0</td>
<td>3.8</td>
</tr>
<tr>
<td>168.3</td>
<td>9.5</td>
<td>5.8</td>
<td>6.0</td>
<td>3.8</td>
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<tr>
<td>219.1</td>
<td>9.5</td>
<td>5.8</td>
<td>6.0</td>
<td>4.2</td>
</tr>
<tr>
<td>273</td>
<td>9.5</td>
<td>5.8</td>
<td>6.0</td>
<td>4.7</td>
</tr>
<tr>
<td>323.9</td>
<td>10.3</td>
<td>5.8</td>
<td>6.4</td>
<td>5.1</td>
</tr>
<tr>
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<td>5.8</td>
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<td>5.3</td>
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<tr>
<td>406.4</td>
<td>10.3</td>
<td>5.8</td>
<td>6.0</td>
<td>5.3</td>
</tr>
</tbody>
</table>

### TABLE 3 Lap Joint Flange—Dimensional Limitations for Tube (Inches-Pound Units)

**NOTE 1**—Key: 0.375 ≤ maximum wall in inches. 0.06 ≤ minimum wall in inches.

<table>
<thead>
<tr>
<th>Tube Diameter, in.</th>
<th>Carbon Steel</th>
<th>Stainless Steel</th>
<th>Copper Nickel</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/8</td>
<td>0.120</td>
<td>0.120</td>
<td>0.120</td>
<td>0.094</td>
</tr>
<tr>
<td>1</td>
<td>0.145</td>
<td>0.138</td>
<td>0.158</td>
<td>0.094</td>
</tr>
<tr>
<td>1 1/4</td>
<td>0.158</td>
<td>0.145</td>
<td>0.177</td>
<td>0.123</td>
</tr>
<tr>
<td>1 1/2</td>
<td>0.217</td>
<td>0.185</td>
<td>0.216</td>
<td>0.123</td>
</tr>
<tr>
<td>2</td>
<td>0.245</td>
<td>0.200</td>
<td>0.235</td>
<td>0.123</td>
</tr>
<tr>
<td>2 1/2</td>
<td>0.275</td>
<td>0.200</td>
<td>0.235</td>
<td>0.123</td>
</tr>
<tr>
<td>3</td>
<td>0.315</td>
<td>0.200</td>
<td>0.235</td>
<td>0.136</td>
</tr>
<tr>
<td>4</td>
<td>0.346</td>
<td>0.200</td>
<td>0.235</td>
<td>0.136</td>
</tr>
<tr>
<td>5</td>
<td>0.375</td>
<td>0.200</td>
<td>0.235</td>
<td>0.136</td>
</tr>
<tr>
<td>6</td>
<td>0.375</td>
<td>0.200</td>
<td>0.235</td>
<td>0.151</td>
</tr>
<tr>
<td>7</td>
<td>0.375</td>
<td>0.200</td>
<td>0.235</td>
<td>0.151</td>
</tr>
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<td>0.375</td>
<td>0.200</td>
<td>0.235</td>
<td>0.167</td>
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<tr>
<td>10</td>
<td>0.375</td>
<td>0.200</td>
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<td>0.186</td>
</tr>
<tr>
<td>12</td>
<td>0.406</td>
<td>0.200</td>
<td>0.250</td>
<td>0.203</td>
</tr>
</tbody>
</table>

9. Allowable Pressure and Temperature

9.1 The allowable pressures and temperatures shall be in accordance with ANSI B31.1 and B31.3, and the individual limitations imposed by the back-up flange, gasket, pipe, and fasteners in accordance with ANSI B16.5.

10. Keywords

10.1 lap joint flange; loose flange joint; slip flange joint; spin flange joint; Van Stone flange
### TABLE 4 Lap Joint Flange—Dimensional Limitations for Pipe

**NOTE 1—**Key—Nearest pipe schedule to max wall (where applicable) $\geq$ Schedule 40. $0.375 \leq$ maximum wall in inches. $0.08 \leq$ minimum wall in inches.

<table>
<thead>
<tr>
<th>Pipe Diameter (NPS)</th>
<th>Material</th>
<th>Carbon Steel</th>
<th>Stainless Steel</th>
<th>Copper and Copper Nickel&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>Schedule 40</td>
<td>0.120</td>
<td>0.120</td>
<td>0.120</td>
<td>Schedule 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.040</td>
<td>0.040</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>3/4</td>
<td>Schedule 40</td>
<td>0.145</td>
<td>0.138</td>
<td>0.158</td>
<td>Schedule 10</td>
</tr>
<tr>
<td></td>
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<td>0.040</td>
<td>0.040</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Schedule 40</td>
<td>0.158</td>
<td>0.145</td>
<td>0.177</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>0.060</td>
<td>0.060</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>1 1/4</td>
<td>Schedule 40</td>
<td>0.217</td>
<td>0.185</td>
<td>0.216</td>
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</tr>
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<td></td>
<td>0.060</td>
<td>0.060</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>1 1/2</td>
<td>Schedule 40</td>
<td>0.245</td>
<td>0.200</td>
<td>0.235</td>
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<td></td>
<td>0.060</td>
<td>0.060</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Schedule 40</td>
<td>0.275</td>
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<td>0.235</td>
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<td></td>
<td>0.060</td>
<td>0.060</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>2 1/2</td>
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<td>0.315</td>
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<td>0.235</td>
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<td>0.060</td>
<td>0.060</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Schedule 40</td>
<td>0.346</td>
<td>0.230</td>
<td>0.235</td>
<td>Schedule 10</td>
</tr>
<tr>
<td></td>
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<td>0.060</td>
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<td>4</td>
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<tr>
<td>5</td>
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<td>6</td>
<td>Schedule 40</td>
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<td>0.230</td>
<td>0.235</td>
<td>Schedule 10</td>
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<tr>
<td>8</td>
<td>Schedule 40</td>
<td>0.375</td>
<td>0.230</td>
<td>0.235</td>
<td>Schedule 10</td>
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<td>0.060</td>
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<td>Schedule 40</td>
<td>0.375</td>
<td>0.230</td>
<td>0.235</td>
<td>Schedule 10</td>
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<td></td>
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<td>0.080</td>
<td>0.080</td>
<td>0.080</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Schedule 40</td>
<td>0.406</td>
<td>0.230</td>
<td>0.250</td>
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</tr>
<tr>
<td>14</td>
<td>standard wall</td>
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<td>0.230</td>
<td>0.250</td>
<td>Schedule 10S</td>
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<td>0.080</td>
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<tr>
<td>16</td>
<td>standard wall</td>
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<td>0.230</td>
<td>0.250</td>
<td>Schedule 10S</td>
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<td>0.080</td>
<td>0.080</td>
<td>0.080</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>For copper-nickel, nearest pipe class to maximum pipe wall is Class 200.
Standard Practice for Establishing Shipbuilding Quality Requirements for Hull Structure, Outfitting, and Coatings

1. Scope
   1.1 This practice consists of three annexes: hull structure, outfitting, and coating. The subject of these annexes was selected for several reasons. Other commercial shipbuilding nations already have in place widely recognized standards of expectations in these areas. These constitute the most significant areas where workmanship is a critical factor in customer satisfaction. The cost associated with the labor involved in these three areas is a significant factor in construction man-hours and overall schedules.

   1.2 The standard criteria provided in this practice are intended to apply to conventional, commercial ship construction. In many cases, specialized, nonconventional vessels using nonstandard materials or built-to-serve sole requirements may require unique acceptance criteria that are beyond those provided in this practice.

2. Referenced Documents
   2.1 ASTM Standards:
      D 4417 Test Methods for Field Measurement of Surface Profile of Blast-Cleaned Steel
      E 337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet-Bulb and Dry-Bulb Temperatures)

   2.2 ISO Standards:
      ISO 8502–3 Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure-Sensitive Tape Method)
      ISO 8502–6 Extraction of Soluble Contaminants for Analysis—The Bresle Method

   2.3 NACE Standards:
      NACE No. 5 Surface Preparation and Cleaning of Steel and Other Hard Materials by High-and Ultrahigh-Pressure Water Jetting Prior to Re-coating (SSPC-SP 12)
      NACE No. 7 Interim Guide and Visual Reference Photographs for Steel Cleaned by Water Jetting (SSPC-VIS 4(1))

   2.4 SSPC Standards:
      SSPC-AB 1 Mineral and Slag Abrasives
      SSPC-AB 2 Specification for Cleanliness of Recycled Ferrous Metallic Abrasives
      SSPC-PA 2 Measurement of Dry Coating Thickness With Magnetic Gages
      SSPC-SP 1 Solvent Cleaning
      SSPC-SP 2 Hand Tool Cleaning
      SSPC-SP 3 Power Tool Cleaning
      SSPC-SP 7 Brush-Off Blast Cleaning
      SSPC-SP 10 Near-White Blast Cleaning
      SSPC-SP 11 Power Toll Cleaning to Bare Metal
      SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High-and Ultrahigh-Pressure Water Jetting Prior to Re-coating (NACE No. 5)
      SSPC-VIS 1-89 Visual Standard for Abrasive Blast Cleaned Steel
      SSPC-VIS 3 Visual Standard for Power- and Hand-Tool Cleaned Steel
      SSPC-VIS 4(1) Interim Guide and Visual Reference Photographs for Steel Cleaned by Water Jetting (NACE No. 7)

   2.5 NSRP Documents:

3. Summary of Practice
   3.1 This practice provides workmanship criteria to be applied to commercial shipbuilding or ship repair, or both. The criteria covers three primary phases of ship construction, that is, hull structure, outfitting, and coatings. Specific criteria to be applied to these phases are covered in the three annexes prior to publication of this practice.
selected from this standard should be as contractually agreed between the ship owner and shipbuilder.

4. Significance and Use

4.1 To achieve success in ship construction, it is necessary for the ship owner and the ship builder to agree on the level of quality in the final product. Classification rules, regulatory requirements, and ship specifications all help to define an acceptable level of construction quality; however, this guidance alone is not sufficient. It is up to the shipbuilder, therefore, to describe the level of workmanship sufficiently that will be reflected in the delivered ship, and for the ship owner to communicate his expectations effectively for the final product.

4.2 It is the intent of this document to contribute to these objectives in the following ways:

4.2.1 To describe a reasonable acceptable level of workmanship for commercial vessels built in the United States.

4.2.2 To provide a baseline from which individual shipyards can begin to develop their own product and process standards in accordance with generally accepted practice in the commercial marine industry.

4.2.3 To provide a foundation for negotiations between the shipbuilder and the ship owner in reaching a common expectation of construction quality.

4.3 The acceptance criteria herein are based on currently practiced levels of quality generally achieved by leading international commercial shipbuilders. These criteria are not intended to be a hard standard with which all U.S. shipyards must comply. Rather, they are intended to provide guidance and recommendations in the key areas that play a major role in customer satisfaction and cost-effective ship construction.

5. Keywords

5.1 coatings; hull structure; outfitting; quality; shipbuilding; workmanship

ANNEXES

(Mandatory Information)

A1. HULL STRUCTURE
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard</th>
<th>Tolerance</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Size and shape compared with correct ones.</td>
<td>± 2</td>
<td>± 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corner angle compared with correct ones</td>
<td>± 1.5</td>
<td>± 2.5</td>
<td>Especially for the depth of floors and girders of double bottom.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Curvature</td>
<td>± 1</td>
<td>± 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Location of member &amp; mark for fitting compared with correct ones.</td>
<td>± 2</td>
<td>± 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Block marking (Panel block) compared with correct ones.</td>
<td>± 2.5</td>
<td>± 3.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Location of member for fitting compared with correct ones.</td>
<td>± 2.5</td>
<td>± 3.5</td>
<td></td>
</tr>
</tbody>
</table>

UNIT: mm

FIG. A1.1 Hull Structure
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Strength Shop member</td>
<td>1000 ( \mu )</td>
<td>2000 ( \mu )</td>
<td>(2nd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field</td>
<td>1500 ( \mu )</td>
<td>3000 ( \mu )</td>
<td>(3rd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5000 ( \mu )</td>
<td>15000 ( \mu )</td>
<td>(Out cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Shop member</td>
<td>100 ( \mu )</td>
<td>200 ( \mu )</td>
<td>(2nd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field</td>
<td>50 ( \mu )</td>
<td>150 ( \mu )</td>
<td>(3rd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 ( \mu )</td>
<td>50 ( \mu )</td>
<td>(Out cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weld groove</td>
<td>100 ( \mu )</td>
<td>200 ( \mu )</td>
<td>(2nd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strength Shop member</td>
<td>400 ( \mu )</td>
<td>800 ( \mu )</td>
<td>(3rd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field</td>
<td>80 ( \mu )</td>
<td>150 ( \mu )</td>
<td>(Out cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Shop member</td>
<td>100 ( \mu )</td>
<td>1500 ( \mu )</td>
<td>(2nd cl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field</td>
<td>50 ( \mu )</td>
<td>1500 ( \mu )</td>
<td>(Out cl)</td>
</tr>
</tbody>
</table>

*FIG. A1.2 Hull Structure*
### I. HULL STRUCTURE

**SHIPBUILDING QUALITY STANDARDS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grade of pitting</td>
<td>1. Grade A pitting is minor and no repair is necessary. Grade B pitting is moderate and is to be repaired as necessary. Grade C pitting is severe and requires repair.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area Ratio</td>
<td>2. Pitting that occurs on the boundary line between Grade A and Grade B can be considered minor and treated as Grade A pitting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depth of pitting</td>
<td>3. Repairs shall be made as follows:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plate Thickness</td>
<td>Depth of pitting ( = )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grind Smooth</td>
<td>Where 0.07 &gt; d, Grind Smooth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: Regardless of plate thickness, at no time should pitting that is 3mm deep or greater be repaired by grinding only.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grind and Weld</td>
<td>Where 0.21 &gt; 0.07, Grind and Weld</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: The area ratio is the estimated percentage of the plate surface that is pitted to the point where the surface appearance is unsatisfactory.</td>
<td></td>
</tr>
</tbody>
</table>

### Surface Flow

<table>
<thead>
<tr>
<th>Grade of surface flow</th>
<th>Applicable to cases where defects are over 20% of thickness, or over 25mm deep and 150mm long.</th>
</tr>
</thead>
</table>

When the removal of a surface defect exposes other significant defects such as cavities, cracks or inclusions, the casting is to be checked using dye penetrant inspection, magnetic particle inspection or ultrasonic inspection and repaired accordingly, using an appropriate method of repair.

### Casting Steel

<table>
<thead>
<tr>
<th>Details of Casting Steel</th>
<th>Where delamination is minor it can be chipped or ground out and built-up with weld metal as shown in Figure (a).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Where minor delamination occurs close to the plate surface grinding or chipping and weld metal build-up should be as shown in Figure (b).</td>
</tr>
<tr>
<td></td>
<td>Repair of moderate delamination should be considered on a case by case basis.</td>
</tr>
</tbody>
</table>

### Delamination

<table>
<thead>
<tr>
<th>Severe delamination, requiring a new plate.</th>
<th>Where delamination is fairly extensive, plating should be cropped out locally and replaced.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Plating</td>
<td>The minimum width of plating to be cropped out is to be as follows:</td>
</tr>
<tr>
<td></td>
<td>Highly Stressed Primary Longitudinal Strength Members: 1600mm</td>
</tr>
<tr>
<td></td>
<td>Moderately Stressed Primary Longitudinal Strength Members: 800mm</td>
</tr>
<tr>
<td></td>
<td>All Other Structural Members: 300mm</td>
</tr>
<tr>
<td></td>
<td>Where severe delamination that affects the whole plate occurs, the whole plate must be replaced.</td>
</tr>
</tbody>
</table>

---

**FIG. A1.3 Hull Structure**
# I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Division</th>
<th>Gas Cutting</th>
<th>UNIT: mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section Sub-section</td>
<td>Item</td>
<td>Standard Range</td>
</tr>
<tr>
<td>Hull structure</td>
<td>Free edge</td>
<td>1) Upper edge of sheer stroke. 2) Strength deck between 0.61 to 1.0 and free edge of opening for shell plate. 3) Main longi strength members.</td>
</tr>
<tr>
<td></td>
<td>Longitudinal &amp; Transverse Strength members</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>3</td>
</tr>
<tr>
<td>Weld groove</td>
<td>Butt weld</td>
<td>Shell plate &amp; upperdeck between 0.61 to 1.0</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Fillet weld</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Straightness of plate edge</td>
<td>Both side submerged arc welding</td>
</tr>
<tr>
<td></td>
<td>Manual welding: semi automatic welding</td>
<td>1.0 ±2.5</td>
</tr>
<tr>
<td></td>
<td>Depth of edge preparation</td>
<td>1.5 ±2.0</td>
</tr>
<tr>
<td></td>
<td>Angle of edge preparation</td>
<td>±2° ±4°</td>
</tr>
<tr>
<td></td>
<td>Length of taper</td>
<td>(if compared with correct sizes)</td>
</tr>
<tr>
<td></td>
<td>Structural members other than double bottom floors and girders.</td>
<td>3.5 ±5.0</td>
</tr>
<tr>
<td></td>
<td>Depth of double bottom floors and girders.</td>
<td>2.5 ±4.0</td>
</tr>
<tr>
<td></td>
<td>Breadth of face bar.</td>
<td>±2.0 ±3.0 ±4.0</td>
</tr>
<tr>
<td></td>
<td>Edge preparation</td>
<td>Automatic welding</td>
</tr>
<tr>
<td></td>
<td>Semi-automatic &amp; manual welding</td>
<td>±2° ±4°</td>
</tr>
</tbody>
</table>

FIG. A1.4 Hull Structure
<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Breadth of flange</td>
<td>±3.0</td>
<td>±5.0</td>
<td>Compared with correct size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depth of web</td>
<td>±3.0</td>
<td>±5.0</td>
<td>Compared with correct size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Angle between flange and web</td>
<td>±2.5</td>
<td>±4.5</td>
<td>Compared with template per 100 mm in breadth of flange</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Curvature or straightness in the plane of flange</td>
<td>±10</td>
<td>±25</td>
<td>Per 10m in length</td>
</tr>
<tr>
<td>Flanged Longitudinal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.5 Hull Structure
## I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stringer angle</td>
<td>Angle</td>
<td>±1.5</td>
<td>±2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compared with template</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Curvature</td>
<td>±1.0</td>
<td>±1.5</td>
<td>Maximum permitted curvature per 100mm length of member.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compared with template</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angle &amp; Built-up plate</td>
<td>Curvature compared with template or check line, per 10m in length.</td>
<td>±2.0</td>
<td>±4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frame &amp; Long</td>
<td>Deviation from Inscribed curve</td>
<td>±1.5</td>
<td>±3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Correct from Inscribed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deviation in Flange angle</td>
<td>±1.5</td>
<td>±3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compared with template</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deviation of Face plate</td>
<td>±1.5</td>
<td>±3.0</td>
<td>per 100mm</td>
</tr>
</tbody>
</table>

FIG. A1.6 Hull Structure
## I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item Description</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanged Brackets</td>
<td>Breadth of flange</td>
<td>Compared with correct size</td>
<td>±3.0</td>
<td>±5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angle between flange and web</td>
<td>Compared with template per 100 mm in breadth of flange</td>
<td>±3.0</td>
<td>±5.0</td>
<td></td>
</tr>
<tr>
<td>Template Box Plate</td>
<td>Actual line of plate edge, compared with template</td>
<td></td>
<td>±2.0</td>
<td>±4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Actual curved surface, compared with template</td>
<td></td>
<td>±2.0</td>
<td>±4.0</td>
<td>For dimensions greater than 1M, ±5.0.</td>
</tr>
<tr>
<td>Section templates</td>
<td>Location of check line for leveling by sight, compared with template (for transverse)</td>
<td></td>
<td>±1.5</td>
<td>±3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Location of check line for leveling by sight, compared with template (for longitudinal)</td>
<td></td>
<td>±1.5</td>
<td>±3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shape, compared with template</td>
<td></td>
<td>±1.5</td>
<td>±3.0</td>
<td></td>
</tr>
<tr>
<td>Other templates</td>
<td>Shape, compared with template</td>
<td></td>
<td>±1.5</td>
<td>±3.0</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.7 Hull Structure
# I. HULL STRUCTURE

## SHIPBUILDING QUALITY STANDARDS

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated bulkhead</td>
<td>Depth of corrugation</td>
<td>±3.0</td>
<td>±6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth of corrugation.</td>
<td>A ±3.0</td>
<td>±6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B ±3.0</td>
<td>±6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrugated wall</td>
<td>Pitch (p)</td>
<td>±6.0</td>
<td>±9.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>±2.0</td>
<td>±3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depth (h)</td>
<td>±2.5</td>
<td>±5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylindrical structure (main post etc.)</td>
<td>Diameters</td>
<td>±0.200</td>
<td>±0.150</td>
<td>But, Max. ±5.0 But, Max. ±7.5</td>
<td></td>
</tr>
<tr>
<td>Curved shell</td>
<td>In regard to the check line (for longitudinal)</td>
<td>±2.5</td>
<td>±5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(for transverse)</td>
<td>±2.5</td>
<td>±5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gap between shell plate and section template</td>
<td>±2.5</td>
<td>±5.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.8 Hull Structure
## I. HULL STRUCTURE

### Block Sub-assembly Including Stern Frame

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Distance between aft edge of boss and aft peak bulkhead (b)</td>
<td>±5</td>
<td>±10</td>
<td>upper gudgeon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Twist of Sub-assembly (c)</td>
<td>±5</td>
<td>±10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deviation of rudder from shaft (d)</td>
<td>±4</td>
<td>±8</td>
<td>lower gudgeon (c) plush</td>
</tr>
</tbody>
</table>

### Special Sub-assembly Rudder

|         |         | Twist of Rudder plate over its length | ±6 | ±10 | Correct or re-assemble partially |

### Main engine bed

|         |         | Flatness of top plate of main engine bed | ±5 | ±10 | |
|         |         | Breadth and length of top plate of main engine bed | ±4 | ±6 | |
|         |         | Others | The same as for flat plate block Sub-assembly |

FIG. A1.9 Hull Structure
## I. HULL STRUCTURE

### Flat plate Sub-assembly

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Breadth of Sub-assembly</td>
<td>±4.0</td>
<td>±6.0</td>
<td>Cut when too long</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of Sub-assembly</td>
<td>±4.0</td>
<td>±6.0</td>
<td>Cut when too long</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Squaresheness of Sub-assembly</td>
<td>±4</td>
<td>±8</td>
<td>Measured difference of diagonal length of final marking line. When the difference is over the limits, correct the final marking line.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion of Sub-assembly</td>
<td>±10</td>
<td>±20</td>
<td>Measured on the face of web or girder.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deviation of Interior members from shell plating</td>
<td>±5.0</td>
<td>±10.0</td>
<td>Excluding the case when interior members are connected by lapped joint.</td>
</tr>
</tbody>
</table>

Accuracy of Dimensions

| Curved plate Sub-assembly | Breadth of Sub-assembly | ±4.0 | ±8.0 | Measured along the girth. Cut when too long. |
| Curved plate Sub-assembly | Length of Sub-assembly  | ±4.0 | ±8.0 | Cut when too long. |
| Curved plate Sub-assembly | Distortion of Sub-assembly | ±10  | ±20  | Measured on face of web or girder. Correct the final marking line when the distortion exceeds the limits. |
| Curved plate Sub-assembly | Squaresheness of Sub-assembly | ±10  | ±15  | Difference of base line to marking or difference of diagonal lengths along marking. Adjust marking where practicable. |
| Curved plate Sub-assembly | Deviation of Interior members from shell plating | The same as for the flat plate Sub-assembly above. |

### Plate Block Sub-assembly

| Breathing of each panel | Length of each panel | Squaresheness of each panel | Distortion of each panel | The same as for the flat plate Sub-assembly above. |
| Distortion of Interior members from skin plating | |

FIG. A1.10 Hull Structure
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Division</th>
<th>Sub-assembly</th>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Twist of</td>
<td>±10</td>
<td>±20</td>
<td>Measured as follows:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sub-assembly</td>
<td></td>
<td></td>
<td>The points A, B and C are established in the same plane. Measure the deviation of point D from that plane. May re-assemble partially when the deviation exceeds the limits.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B.L. = baseline</td>
<td></td>
<td></td>
<td>Accuracy of this dimension</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deviation of</td>
<td>±5</td>
<td>±10</td>
<td>The same as for the flat plate Sub-assembly (previous page)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>upper/lower panel from t or B.L.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deviation of</td>
<td>±5</td>
<td>±10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>upper/lower panel from t or FR.L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Breadth of each panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length of each panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Distortion of each panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deviation of interior members from skin plating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Twist of</td>
<td>±15</td>
<td>±25</td>
<td>The same as for the flat plate Sub-assembly (previous page)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sub-assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deviation of</td>
<td>±7</td>
<td>±15</td>
<td>Re-assemble partially when the deviation exceeds the limits</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>upper/lower panel from t or B.L.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deviation of</td>
<td>±7</td>
<td>±15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>upper/lower panel from t or FR.L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Distance between</td>
<td>±5.0</td>
<td>±10.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>upper/lower gudgeon (a)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.11 Hull Structure
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Dimensions</td>
<td>Length</td>
<td>Length between Perpendiculars</td>
<td>±50.0</td>
<td>Per 100m</td>
<td>Applied to ships of 100 meters length and below. For the convenience of the measurement the point where the keel is connected to the curve of the stem may be substituted for the fore perpendicular in the measurement of the length.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length between aft edge of boss and main engine</td>
<td>±25.0</td>
<td>Not defined</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>Molded breadth Amidships</td>
<td>±15.0</td>
<td>Not defined</td>
<td>Applied to ships of 15 meters breadth and above. Measured on the upper deck.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Molded depth Amidships</td>
<td>±10.0</td>
<td>Not defined</td>
<td>Applied to ships of 10 meters depth and above.</td>
</tr>
<tr>
<td>Flatness of Keel</td>
<td></td>
<td>Deformation for the whole length</td>
<td>±25.0</td>
<td>Not defined</td>
<td>Ups(-) and Downs(+) against the check line of keel sighting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deformation for the distance between two adjacent bulkheads</td>
<td>±15.0</td>
<td>Not defined</td>
<td>Sighting by the transit or using slits.</td>
</tr>
<tr>
<td>Forebody Alignment</td>
<td></td>
<td>Alignment of fore-body to baseline.</td>
<td>±30.0</td>
<td>Not defined</td>
<td>Ups(-) and Downs(+) against the baseline of the keel at the foremost frame on the flat part of the keel.</td>
</tr>
<tr>
<td>Deformation of hull form</td>
<td></td>
<td>Alignment of aft-body to baseline.</td>
<td>±20.0</td>
<td>Not defined</td>
<td>Ups(-) and Downs(+) against the baseline of the keel at the aft-perpendicular.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rise of floor Amidships</td>
<td>±15.0</td>
<td>Not defined</td>
<td>The height of the lower turn of the bilge, compared with the planned height. Measured from the plane passing through the outer surface of the keel plate.</td>
</tr>
</tbody>
</table>

**FIG. A1.12 Hull Structure**
<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. HULL STRUCTURE</td>
<td></td>
<td>Shell plate and face plate between 0.6l @</td>
<td>over 90⁰ continuous 650.5</td>
<td>Repair using fine electrode. (Avoid short beads for higher tensile steel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>d≤0.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compared with Correct ones (l,d)</td>
<td></td>
<td>When over tolerance limits, weld-up. (Avoid short beads for higher tensile steel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leg length</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shell plate between 0.6LOX</td>
<td></td>
<td>When over tolerance limits, repair by line heating or re-weld after cutting and re-fitting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fore and Aft shell plating and Transverse strength member</td>
<td>WS6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>WS8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short bead</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50HT . Cast steel TMCP type 50HT (ceq.≥0.36%)</td>
<td>250</td>
<td>In case where short bead is unavoidable, preheat to 225⁰C. If short bead is made inadvertently, remove the bead by grinding and weld over length of visible crack.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade E of mild steel TMCP type 50HT (ceq.≥0.36%)</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repairing of welding bead</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50HT . Cast steel TMCP type 50HT (ceq.≥0.36%)</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade E of mild steel TMCP type 50HT (ceq.≥0.36%)</td>
<td>230</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.13 Hull Structure
<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc strike</td>
<td></td>
<td>.50HT</td>
<td>not allowed</td>
<td>In case where arc-strike is made inadvertently, remove the hardened zone by grinding or weld over length of short bead on the arc-strike.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.Cost steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.Grade E of mild steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.TMCP type 50HT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-heating</td>
<td>Temperature</td>
<td>TMCP type 50HT (Ceq≤0.36%)</td>
<td>T≤50°C</td>
<td>In case where Ceq of each plate are different in joint, tolerance of higher Ceq to be applied.</td>
</tr>
<tr>
<td></td>
<td>required pre-heating</td>
<td>.50HT</td>
<td>T≤55°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.Cost steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.Grade E of mild steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.TMCP type 50HT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mild steel</td>
<td>T≤55°C</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.14 Hull Structure
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum distance of weld to adjacent weld</td>
<td>Built weld to butt weld</td>
<td>a230</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Main structure</td>
<td>a210</td>
<td>Where beads are parallel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other structure</td>
<td>a20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Main structure</td>
<td>a20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other structure</td>
<td>a25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Built weld to filler weld</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stiffening member located perpendicular to plate.</td>
<td></td>
<td>Gap between members is to be less than 3mm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>when C&gt;3, any following treatment can taken.</td>
<td>C≤3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stiffening member located obliquely to plate (without edge preparation)</td>
<td>BS3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Through plate and flange plate</td>
<td>C1≤3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C1 &gt; C2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A1.15 Hull Structure**
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment of fillet joint</td>
<td></td>
<td>Strength member</td>
<td>a±1/3t&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>1/3t&lt;sub&gt;2&lt;/sub&gt;≤ a ≤1/2t&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>a±1/3t&lt;sub&gt;2&lt;/sub&gt;</td>
<td>a±1/2t&lt;sub&gt;2&lt;/sub&gt;</td>
<td>a&gt;1/2t&lt;sub&gt;2&lt;/sub&gt; re-fitting</td>
</tr>
<tr>
<td>Differences</td>
<td>between the beam</td>
<td>Beam</td>
<td>a≤3</td>
<td>a≤5</td>
<td>The figure indicates the tolerance that the members can be welded by pulling without taking apart.</td>
</tr>
<tr>
<td></td>
<td>and the frame</td>
<td>Beamknee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frame</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>a:Difference</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Gap before welding    | Fillet weld          |                               | a≤2            | a≤3              | 1) 3≤a≤5
Increased leg length Rule leg +t<sub>0</sub>-2 2) 5≤a≤16
Welding with bevel preparation or Liner treatment |
|                       |                      |                               |                |                  | Welding with bevel preparation              |
|                       |                      |                               |                |                  | To make bevel edge of web to 30°~45°, attach the backing material, and after welding, remove it. Then weld the opposite side. Liner treatment |
|                       |                      |                               |                |                  | Liner treatment                             |
|                       |                      |                               |                |                  | 3) a>16
Liner treatment or partial renew |

**FIG. A1.16 Hull Structure**
# I. HULL STRUCTURE

## Division

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Butt weld (manual welding)</td>
<td>2σ ≤ 3.5</td>
<td>a ≤ 5</td>
<td>1. (5σ ≤ 16) After welding, remove backing material, chip and finish weld.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Butt weld (automatic welding)</td>
<td>0σ ≤ 0.8</td>
<td>a ≤ 5</td>
<td>Where predicted to burn through, weld sealing bead.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual or CO(_2) submerged arc welding</td>
<td>0σ ≤ 3.5</td>
<td>a ≤ 5</td>
<td>Where (a &gt; 1) is over 5mm, use manual welding.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One side submerged arc welding with flux copper backing or flux backing</td>
<td>0σ ≤ 1.0</td>
<td>a ≤ 3</td>
<td>Where predicted to burn through, weld sealing bead.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One side submerged arc welding with fiber backing</td>
<td>0σ ≤ 4</td>
<td>a ≤ 7</td>
<td>Where predicted to burn through, adjust by scattering of metal powder or weld sealing bead.</td>
</tr>
</tbody>
</table>

FIG. A1.17 Hull Structure
# I. HULL STRUCTURE

## Scope of Staging Sockets and Lifting Lugs to be Removed

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Lifting Lugs</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staging sockets</td>
<td>In tank</td>
<td>Not to be removed.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In engine room</td>
<td>Parts of ruin ing appearance and interfering with clear passage.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In hold</td>
<td>Under side of hold and hatch coaming.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exposed parts of shell upp DK etc..</td>
<td>To be removed.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifting lugs</td>
<td>In tank</td>
<td>Not to be removed except disturbance of passage.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In engine room</td>
<td>Part of ruin ing appearance and passages.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In hold</td>
<td>To be removed except back of deck.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exposed parts of shell upp DK etc..</td>
<td>To be removed.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Lifting lugs subjected to fatigue to be removed.
1. Parts ruin ing appearance and passage to be removed flush to base plate.
2. Others to be removed by gas cutting at the bond zone.

[Diagram: Cut along this line]
## I. HULL STRUCTURE

### SHIPBUILDING QUALITY STANDARDS

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5. CO₂ one side welding (with backing strip)</td>
<td>2a ≤ b ≤ 8</td>
<td>a ≤ 16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Electro gas welding</td>
<td>9a ≤ 16</td>
<td>a ≤ 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7. Simplified electric gas welding</td>
<td>2a ≤ 8</td>
<td>a ≤ 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lap weld</td>
<td>a ≤ 2</td>
<td>a ≤ 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alignment of butt joint</td>
<td>a ≤ 0.15t (max 3)</td>
<td>a &gt; 0.15t or a &gt; 3</td>
<td>Refitting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strength member</td>
<td>a ≤ 0.2t (max 3)</td>
<td>a &gt; 0.2t or a &gt; 3</td>
<td>Refitting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>a ≤ 0.2t (max 3)</td>
<td>a &gt; 0.2t or a &gt; 3</td>
<td>Refitting</td>
</tr>
</tbody>
</table>

### Fitting Accuracy

#### Gap before Welding

- Parts requiring good appearance:
  - Outside surface of shell plates, Exposed deck, Exposed superstructure
  - Grind flush
  - See Annex A3 for surfaces that are to be painted

- Parts not requiring good appearance:
  - Inside of tank, Inside of ceiling, Deck to be shield with deck composition etc.
  - Grind only conspicuous parts finishing
  - See Annex A3 for surfaces that are to be painted

### Surface defect

- Scar:
  - Depth (d) ≤ 10a
  - Length (a) ≤ 10
  - d ≤ 0.8
  - a ≤ 1.0
  - a ≤ 1.0

---

*FIG. A1.19 Hull Structure*
### I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell plate</td>
<td>Parallel part side</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parallel part bottom</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fore and aft part</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Double bottom tank top plate</td>
<td></td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Bulkhead</td>
<td>Longi Bulkhead</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trans Bulkhead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swash Bulkhead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength deck</td>
<td>Parallel part (Between 0.6@)</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fore and aft part</td>
<td>6</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covered part</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Second deck</td>
<td>Exposed part</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covered part</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Fore-castle deck</td>
<td>Exposed part</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Poop deck</td>
<td>Covered part</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Super Structure deck</td>
<td>Exposed part</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covered part</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Cross deck</td>
<td></td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>House bulkhead</td>
<td>Outside bulkhead</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inside bulkhead</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covered part</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Interior member</td>
<td>Web of girder, trans</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Floor and girder of double bottom</td>
<td></td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A1.20 Hull Structure**
<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item Description</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dc200</td>
<td></td>
<td>Strength member in skin plate</td>
<td>A or B</td>
<td>Open the hole to over 75mm or 200mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>F or G</td>
<td>In case G, open the hole to over 200mm</td>
</tr>
<tr>
<td>D≥200</td>
<td></td>
<td>Strength member in skin plate</td>
<td>D</td>
<td>Method of treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>F or G</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Serration, Scallop Slot</td>
<td></td>
<td></td>
<td>Close by butt welding, Close with lapping piece. Where it is difficult from structural point of view to open the hole over 200mm, pre-heat and use a low hydrogen electrode. Inspect by radiographic or ultrasonic inspection.</td>
</tr>
</tbody>
</table>

FIG. A1.21 Hull Structure
## I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation of frames</td>
<td></td>
<td>Shell plate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parallel part</td>
<td>±2σ/1000</td>
<td>±3σ/1000</td>
<td>(+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fore and aft part</td>
<td>±3σ/1000</td>
<td>±4σ/1000</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deck and top plate of double bottom</td>
<td>±3σ/1000</td>
<td>±4σ/1000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulkhead</td>
<td>±4σ/1000</td>
<td>±4σ/1000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accommodation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outside bulkhead</td>
<td>±2σ/1000</td>
<td>±3σ/1000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>±5σ/1000</td>
<td>±6σ/1000</td>
<td></td>
</tr>
<tr>
<td>Deviation of frames</td>
<td></td>
<td>Distortion of deep girder and transverse (at the part of upper edge and flange)</td>
<td>±1σ/1000</td>
<td>±2σ/1000 (max 10)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of span</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion of longitudinal and transverse frames, beam and stiffener (at the part of flange).</td>
<td>1000σe</td>
<td>3 × 2σ/1000 (max 10) 6 × 2σ/1000 (max 13)</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td>Distortion of M pillar between decks</td>
<td></td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion of cross tie</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion of fore and aft direction, e, (cross tie only)</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion of fore and aft direction, e, (cross tie + trans web)</td>
<td>12</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion of tripping bolt and small stiffener with web plate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distortion at the port of free edge</td>
<td>a=2 + b/100</td>
<td>a=5 + b/100</td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A1.22 Hull Structure**
## I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Division</th>
<th>Miscellaneous</th>
<th>UNIT: mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
<td>Sub-section</td>
<td>Item</td>
</tr>
<tr>
<td>Sub assembly and assembly welded joint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painting for welded joint of tightness test or construction inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erection welded joint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draft Mark</td>
<td></td>
<td>Compared to the template</td>
</tr>
<tr>
<td>Freeboard Mark</td>
<td></td>
<td>Compared to the template</td>
</tr>
</tbody>
</table>

FIG. A1.23 Hull Structure
# I. HULL STRUCTURE

<table>
<thead>
<tr>
<th>Section Sub-section</th>
<th>Item</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
<td>±5</td>
<td>±10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>±5</td>
<td>±10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference of diagonal length</td>
<td>±10</td>
<td>±15</td>
<td></td>
</tr>
<tr>
<td>Hatch Coaming</td>
<td>End coaming</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Side coaming</td>
<td>±5</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deformation per one meter (random)</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth and Height</td>
<td>±4</td>
<td>±7</td>
<td></td>
</tr>
<tr>
<td>Opening of steel wall</td>
<td>Still height</td>
<td>0~15</td>
<td>-10~+30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deformation (per 1m)</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>Opening of deck (through type)</td>
<td>Length</td>
<td>±3</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>-3~+2</td>
<td>-5~+3</td>
<td></td>
</tr>
<tr>
<td>Opening of deck (not through type)</td>
<td>Length</td>
<td>-3~+2</td>
<td>-5~+3</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A1.24 Hull Structure
A2. OUTFITTING
## I. PIPING

### Section A. PIPE FABRICATION

#### 1. STRAIGHT PIPE

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item Description</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indicated length of pipe on drawing</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>l</td>
<td>±6</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Length tolerance</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2. BENT PIPE

##### a. Single direction bending

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated lengths of pipe on drawing</td>
<td><img src="image2.png" alt="Diagram" /></td>
<td>l &amp; l₂</td>
<td>±6</td>
<td>Not Defined</td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design bending angle</td>
<td>α</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bend tolerance</td>
<td>α₁</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

##### b. Two direction bending

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated lengths of pipe on drawing</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>l₁ &amp; l₂</td>
<td>±6</td>
<td>Not Defined</td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design bending angles</td>
<td>α</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bend tolerance</td>
<td>α₁</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

##### c. Three direction bending

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated lengths of pipe on drawing</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td>l₁ &amp; l₂</td>
<td>±5</td>
<td>Not Defined</td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design bending angles</td>
<td>α</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bend tolerance</td>
<td>α₁</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3. Branch pipe

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated lengths of pipe on drawing</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td>l₁ &amp; l₂</td>
<td>±5</td>
<td>Not Defined</td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length tolerance</td>
<td>d₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design angle</td>
<td>α</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle tolerance</td>
<td>α₁</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*FIG. A2.1 Piping*
### I. PIPING

#### A. PIPE FABRICATION

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. PENETRATION PIECE</td>
<td>Indicated lengths of pipe on drawing</td>
<td><img src="image" alt="Diagram of indicated lengths" /></td>
<td></td>
<td></td>
<td>±0.4</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Length tolerance</td>
<td><img src="image" alt="Diagram of length tolerance" /></td>
<td></td>
<td></td>
<td>±0.4</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Design penetration angle</td>
<td><img src="image" alt="Diagram of design penetration angle" /></td>
<td></td>
<td></td>
<td>±1°</td>
<td>Not Defined</td>
</tr>
</tbody>
</table>

#### 5. FLANGES

<table>
<thead>
<tr>
<th>Section</th>
<th>Item</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>b.</td>
<td>Distortion of flange face</td>
<td><img src="image" alt="Diagram of distortion of flange face" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>Distance between fillet and butt welding bead</td>
<td><img src="image" alt="Diagram of distance between fillet and butt welding bead" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>Attachment of flange to pipe</td>
<td><img src="image" alt="Diagram of attachment of flange to pipe" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>Thread extension past nut</td>
<td><img src="image" alt="Diagram of thread extension past nut" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>Distance between pipe and bending area</td>
<td><img src="image" alt="Diagram of distance between pipe and bending area" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.</td>
<td>Alignment of flanges</td>
<td><img src="image" alt="Diagram of alignment of flanges" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.2 Piping
## I. PIPING

### A. PIPE FABRICATION

#### Section 6. COUPLINGS

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Coupling (sleeve)</td>
<td>Length of coupling</td>
<td>L</td>
<td>23t</td>
<td>not defined</td>
<td>l, t vary according to pipe diameter</td>
<td></td>
</tr>
<tr>
<td>a. Coupling (sleeve)</td>
<td>Length of pipe inside coupling</td>
<td>L</td>
<td>23t</td>
<td>not defined</td>
<td>l, t vary according to pipe diameter</td>
<td></td>
</tr>
<tr>
<td>a. Coupling (sleeve)</td>
<td>Distance between pipes inside coupling</td>
<td>L</td>
<td>23t</td>
<td>not defined</td>
<td>l, t vary according to pipe diameter</td>
<td></td>
</tr>
<tr>
<td>a. Coupling (sleeve)</td>
<td>Pipe thickness</td>
<td>t</td>
<td>1~3</td>
<td>not defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Coupling (sleeve)</td>
<td>Distance between inside of coupling and outside of pipe</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Coupling misalignment</td>
<td>Distance between inside of coupling and outside of pipe</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Coupling misalignment</td>
<td>Angle misalignment</td>
<td>θ</td>
<td>≤2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Coupling bell &amp; socket</td>
<td>Distance between inside of coupling and outside of pipe</td>
<td>d</td>
<td>≤0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Coupling bell &amp; socket</td>
<td>Distance pipe inserted in socket</td>
<td>l</td>
<td>25t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Coupling bell &amp; socket</td>
<td>Pipe thickness</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Dresser coupling distance between pipe ends</td>
<td>Distance between pipe ends</td>
<td>d</td>
<td>≤10</td>
<td></td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>e. Dresser coupling pipe misalignment</td>
<td>Amount of misalignment</td>
<td>d</td>
<td>≤13</td>
<td>≤15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### B. PIPE BENDING

#### Section 1. ELLIPTICITY (out of roundness)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Tolerance Limits (unit: %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Steel and non-ferrous pipe</td>
<td>Ellipticity=(D-D)×100 (%)</td>
<td>D</td>
<td>R52A 2AKRS3A 3AKRS4A 4AKP</td>
</tr>
<tr>
<td>a. Steel and non-ferrous pipe</td>
<td>Outside dia. of pipe before manufacturing</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>a. Steel and non-ferrous pipe</td>
<td>Major dia. of bent pipe</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>a. Steel and non-ferrous pipe</td>
<td>Minor dia. of bent pipe</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>a. Steel and non-ferrous pipe</td>
<td>Nominal dia. Bending radius</td>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.3 Piping
# I. PIPING

## B. PIPE BENDING

### 1. ELLIPTICITY (out of roundness)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Tolerance Limits (unit; %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Al-brass &amp; CuNi pipe</td>
<td>Ellipticity ( \frac{(D-D_1) \times 100}{D} )</td>
<td><img src="image" alt="Diagram" /></td>
<td>Bending</td>
</tr>
<tr>
<td></td>
<td>Outside dia. of pipe before manufacturing</td>
<td></td>
<td>RS2A</td>
</tr>
<tr>
<td></td>
<td>Major dia. of bent pipe</td>
<td></td>
<td>2ARKS3A</td>
</tr>
<tr>
<td></td>
<td>Minor dia. of bent pipe</td>
<td></td>
<td>3AKR54A</td>
</tr>
<tr>
<td></td>
<td>Nominal dia.</td>
<td></td>
<td>4AKR</td>
</tr>
<tr>
<td></td>
<td>Bending radius</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2. REDUCTION IN WALL THICKNESS

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Tolerance Limits (unit; %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Steel pipe</td>
<td>Reduction in wall thickness ( \frac{(t-t_1) \times 100}{t} )</td>
<td><img src="image" alt="Diagram" /></td>
<td>Bending</td>
</tr>
<tr>
<td></td>
<td>Original wall thickness</td>
<td></td>
<td>RS2A</td>
</tr>
<tr>
<td></td>
<td>Wall thickness after bending</td>
<td></td>
<td>2ARKS3A</td>
</tr>
<tr>
<td></td>
<td>Nominal dia.</td>
<td></td>
<td>3AKR54A</td>
</tr>
<tr>
<td></td>
<td>Bending radius</td>
<td></td>
<td>4AKR</td>
</tr>
<tr>
<td>b. Copper pipe</td>
<td>Reduction in wall thickness ( \frac{(t-t_1) \times 100}{t} )</td>
<td><img src="image" alt="Diagram" /></td>
<td>Bending</td>
</tr>
<tr>
<td></td>
<td>Original wall thickness</td>
<td></td>
<td>RS2A</td>
</tr>
<tr>
<td></td>
<td>Wall thickness after bending</td>
<td></td>
<td>2ARKS3A</td>
</tr>
<tr>
<td></td>
<td>Nominal dia.</td>
<td></td>
<td>3AKR54A</td>
</tr>
<tr>
<td></td>
<td>Bending radius</td>
<td></td>
<td>4AKR</td>
</tr>
<tr>
<td>c. Al-brass &amp; CuNi pipe</td>
<td>Reduction in wall thickness ( \frac{(t-t_1) \times 100}{t} )</td>
<td><img src="image" alt="Diagram" /></td>
<td>Bending</td>
</tr>
<tr>
<td></td>
<td>Original wall thickness</td>
<td></td>
<td>RS2A</td>
</tr>
<tr>
<td></td>
<td>Wall thickness after bending</td>
<td></td>
<td>2ARKS3A</td>
</tr>
<tr>
<td></td>
<td>Nominal dia.</td>
<td></td>
<td>3AKR54A</td>
</tr>
<tr>
<td></td>
<td>Bending radius</td>
<td></td>
<td>4AKR</td>
</tr>
</tbody>
</table>

### 3. SWELL & WRINKLE DISTORTION

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Tolerance Limits (unit; %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. All pipe materials</td>
<td>Amount of swell distortion</td>
<td><img src="image" alt="Diagram" /></td>
<td>h or h,</td>
</tr>
<tr>
<td></td>
<td>Amount of wrinkle distortion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nominal dia.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## I. PIPING

### Division C. PIPE HANGERS

<table>
<thead>
<tr>
<th>Section</th>
<th>1. U-BOLT</th>
<th><strong>SHIPBUILDING QUALITY STANDARDS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sub-section</strong></td>
<td><strong>Item</strong></td>
<td><strong>Figure</strong></td>
</tr>
<tr>
<td>a.</td>
<td>Height difference between ends of U-bolt</td>
<td>Diameter of U-bolt</td>
</tr>
<tr>
<td>b.</td>
<td>Pitch of U-bolt</td>
<td>Difference between required and actual location</td>
</tr>
<tr>
<td>c.</td>
<td>Clearance between pipe &amp; U-bolt or flat steel band</td>
<td>Clearance between top of pipe &amp; hanger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearance between bottom of pipe &amp; hanger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearance between side of pipe &amp; hanger</td>
</tr>
<tr>
<td>d.</td>
<td>Thread extension from nut for U-bolt or flat steel band</td>
<td>Length of thread projection beyond nut</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diameter of bolt</td>
</tr>
</tbody>
</table>

### Section 2. FLAT STEEL BAND

| **Sub-section** | **Item** | **Figure** | **Standard Range** | **Tolerance Limits** | **Remarks** |
| a. | Hanger height | Required height of hanger | h | -2 \( \pm 0 \) | not defined |
| | | Dimensional variation | d | | |
| b. | Pitch of bolt holes | Required pitch between bolt holes | l | \( \pm 2 \) | not defined |
| | | Dimensional variation | d | | |

### Section 3. DISTANCE BETWEEN PIPE HANGERS

<table>
<thead>
<tr>
<th>Pipe nominal diameter</th>
<th>Maximum hanger spacing</th>
<th>Pipe nominal diameter</th>
<th>Maximum hanger spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.4 m</td>
<td>125</td>
<td>4.5 m</td>
</tr>
<tr>
<td>15</td>
<td>1.6 m</td>
<td>150</td>
<td>5.0 m</td>
</tr>
<tr>
<td>20</td>
<td>1.8 m</td>
<td>200</td>
<td>5.0 m</td>
</tr>
<tr>
<td>25</td>
<td>2.1 m</td>
<td>250</td>
<td>5.5 m</td>
</tr>
<tr>
<td>32</td>
<td>2.4 m</td>
<td>300</td>
<td>6.0 m</td>
</tr>
<tr>
<td>40</td>
<td>2.6 m</td>
<td>350</td>
<td>6.0 m</td>
</tr>
<tr>
<td>50</td>
<td>2.8 m</td>
<td>400</td>
<td>6.0 m</td>
</tr>
<tr>
<td>65</td>
<td>3.2 m</td>
<td>500</td>
<td>7.0 m</td>
</tr>
<tr>
<td>80</td>
<td>3.5 m</td>
<td>600</td>
<td>7.0 m</td>
</tr>
<tr>
<td>100</td>
<td>4.0 m</td>
<td>700</td>
<td>7.0 m</td>
</tr>
</tbody>
</table>

**FIG. A2.5 Piping**
## I. PIPING

### Division E. REACH RODS

#### Section 1. MANUFACTURING OF REACH ROD

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Clearance between reach rod and bearing</td>
<td>Diameter of reach rod</td>
<td>D</td>
<td>D225</td>
<td>0.5≤a≤1.5</td>
<td>not defined</td>
</tr>
<tr>
<td></td>
<td>Clearance between reach rod &amp; bearing</td>
<td>a</td>
<td>D232</td>
<td>0.5≤a≤2.0</td>
<td>not defined</td>
</tr>
<tr>
<td>b. Straightness of spindle (per 5 m length)</td>
<td>Deflection of rod</td>
<td>a</td>
<td>5≤a≤10</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>c. Clearance between reach rod and joint piece</td>
<td>Clearance between reach rod and joint piece</td>
<td>a</td>
<td>0.25≤a≤1.0</td>
<td>not defined</td>
<td></td>
</tr>
</tbody>
</table>

#### Section 2. FITTING OF REACH ROD

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Spindle end spacing &amp; free end spacing of taper pin</td>
<td>Spindle end spacing</td>
<td>a</td>
<td>5≤a≤8</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free end spacing of taper pin</td>
<td>b</td>
<td>5≤b≤8</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>b. Straightness of reach rod (per 5 m length)</td>
<td>Deflection of rod</td>
<td>a</td>
<td>5≤a≤10</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>c. Misalignment between valve spindle and reach rod</td>
<td>Misalignment distance</td>
<td>a</td>
<td>5≤a≤10</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>d. Fitting angle of deck stand</td>
<td>Angle deviation from vertical</td>
<td>a'</td>
<td>5≤a'≤10</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>e. Deviation of reach rod from perpendicular to bearing</td>
<td>Angle deviation from normal</td>
<td>a'</td>
<td>5≤a'≤10</td>
<td>not defined</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.6 Piping
### I. PIPING

#### Division F. BELLMOUTHS

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Nominal Diameter (mm)</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A-TYPE BELLMOUTH</td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>80</td>
<td>( \pm 15 )</td>
<td>( \pm 20 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td>100</td>
<td>( \pm 20 )</td>
<td>( \pm 25 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image2.png" alt="Diagram" /></td>
<td>125</td>
<td>( \pm 25 )</td>
<td>( \pm 30 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td>150</td>
<td>( \pm 30 )</td>
<td>( \pm 35 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>200</td>
<td>( \pm 35 )</td>
<td>( \pm 40 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. B-TYPE BELLMOUTH</td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td>250</td>
<td>( \pm 45 )</td>
<td>( \pm 50 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td>300</td>
<td>( \pm 50 )</td>
<td>( \pm 55 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td>350</td>
<td>( \pm 55 )</td>
<td>( \pm 60 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td>400</td>
<td>( \pm 60 )</td>
<td>( \pm 65 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image6.png" alt="Diagram" /></td>
<td>450</td>
<td>( \pm 65 )</td>
<td>( \pm 70 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td>500</td>
<td>( \pm 70 )</td>
<td>( \pm 75 )</td>
<td></td>
</tr>
<tr>
<td>3. C-TYPE BELLMOUTH</td>
<td>Height of bellmouth above bottom of tank</td>
<td>( l )</td>
<td><img src="image7.png" alt="Diagram" /></td>
<td>550</td>
<td>( \pm 75 )</td>
<td>( \pm 80 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height tolerances</td>
<td>( d )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A.2.7 Piping**
# I. HULL OUTFITTING

## Division
I-A WATER TIGHT STEEL HATCH COVER

## Section
1. HATCH COVER (SINGLE PULL TYPE)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Tolerance Limita(i.e.)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of hatch cover</td>
<td>Length (1 hatch)</td>
<td>61</td>
<td>±5</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Length (1 panel)</td>
<td>62</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Breath</td>
<td>63</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Height of hatch cover</td>
<td>64</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals (1 hatch)</td>
<td>65</td>
<td>±1</td>
<td>Condition where each cover is ranged without closely tightening</td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals (1 panel)</td>
<td>66</td>
<td>±1</td>
<td>Condition where each cover is ranged and tightened</td>
</tr>
<tr>
<td></td>
<td>Deflection of side plate in the vertical direction</td>
<td>66</td>
<td>±3</td>
<td>Actual dimension</td>
</tr>
<tr>
<td></td>
<td>Bend of side plate in the transverse direction</td>
<td>68</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Bend of end plate in the transverse direction</td>
<td>69</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Deformation of top plate</td>
<td>610</td>
<td>±4</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Flatness of undersurface of hatch cover (1 panel)</td>
<td>610</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td>2. Deflection of side end and top plate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deflection of end plate in the vertical direction</td>
<td>67</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Bend of side plate in the transverse direction</td>
<td>68</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Bend of end plate in the transverse direction</td>
<td>69</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td></td>
<td>Flatness of undersurface of hatch cover (1 panel)</td>
<td>610</td>
<td>±3</td>
<td>Not Defined</td>
</tr>
<tr>
<td>3. Dimension of wheel after installing</td>
<td>Dimension of balancing wheel after installing</td>
<td>611</td>
<td>±12</td>
<td>±3</td>
</tr>
<tr>
<td></td>
<td>Height of balancing wheel</td>
<td>612</td>
<td>±12</td>
<td>±3</td>
</tr>
<tr>
<td></td>
<td>Dimension of wheel after installing</td>
<td>613</td>
<td>±12</td>
<td>±3</td>
</tr>
<tr>
<td></td>
<td>Height of wheel</td>
<td>614</td>
<td>±12</td>
<td>±3</td>
</tr>
<tr>
<td></td>
<td>Pitch of installed wheel</td>
<td>615</td>
<td>±12</td>
<td>±4</td>
</tr>
</tbody>
</table>

*Fig. A2.8 Hull Outfitting*
## I. HULL OUTFITTING

### Division

I-A WATER TIGHT STEEL HATCH COVER

### Section

1. HATCH COVER (SINGLE PULL TYPE)

#### Sub-section

4. Intermediate hinge and water tightness

#### Item

- Height from base line to packing gutter
- Breadth of packing gutter
- Deviation between compression bar and packing
- Compressed depth of packing
- Deviation between top plates
- Deviation between side plates
- Clearance between hatch covers

#### Figure

![Diagram](image)

#### Standard Range (mm)

- 6
- 6.7
- 6.8
- 6.9
- 6.19
- 6.2
- 6.2
- 6.23

#### Tolerance Limits (mm)

- ±1
- ±1
- ±1
- ±5
- ±2
- ±2
- ±2
- ±3
- 0
- -5 ± 10

#### Remarks

- ±thickness of compression bar
- Compressed depth of packing surrounding hatch cover to be in accordance with this item.
- * not defined

#### 5. Installing position of snap for quick acting cleat

- Longitudinal deviation
- Vertical deviation

#### Figure

![Diagram](image)

#### Standard Range (mm)

- 6.24
- 6.25

#### Tolerance Limits (mm)

- ±4
- ±4

#### Remarks

- Refer to note

#### 6. Clearance between hatch cover and hatch coaming

- Touchpiece type
- Directly of touched type
- Rest pad type

#### Figure

![Diagram](image)

#### Standard Range (mm)

- 6.26
- 6.27
- 6.28

#### Tolerance Limits (mm)

- ±1
- ±3
- ±1

#### Remarks

- Refer to note

---

**Note**

Every touchpiece of A or C type to be in touch with end and side girder of hatch cover or rest are of hatch cover.

For type B, end and side girder of hatch cover to be in touch with the coaming top plate at least one position in any 3 meters.

### Section

2. HATCH COVER (SINGLE PULL TYPE)

#### 1. Dimension of hatch coaming

- Length
- Breadth
- Difference between diagonals

#### Figure

![Diagram](image)

#### Standard Range (mm)

- 6.1
- 6.2

#### Tolerance Limits (mm)

- ±5
- ±5
- ±10
- ±10
- ±15

#### Remarks

- * to be in accordance with hull specification.
- L = designed dimension
- L = actual dimension

---

FIG. A2.9 Hull Outfitting

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## I. HULL OUTFITTING

### Division I-A WATER TIGHT STEEL HATCH COVER

#### Section 2. HATCH COMINGS (SINGLE PULL TYPE)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>* End coaming</td>
<td>63</td>
<td>±1</td>
<td>±1</td>
<td>To be in accordance with hull specification.</td>
</tr>
<tr>
<td></td>
<td>* Side coaming</td>
<td>64</td>
<td>±2</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Deflection in any one meter flat end and side coaming</td>
<td>65</td>
<td>±2</td>
<td>±2</td>
<td></td>
</tr>
</tbody>
</table>

3. Installing dimension of compression bar

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installing position longitudinal deviation</td>
<td>66</td>
<td>±2</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td>Transverse deviation</td>
<td>67</td>
<td>±3</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>Deviation from center line of cover packing</td>
<td>68</td>
<td>±3</td>
<td>±3</td>
<td></td>
</tr>
</tbody>
</table>

4. Installing dimension of guide roll and ramp

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installing position of guide roll</td>
<td>610</td>
<td>±1</td>
<td>±1</td>
<td></td>
</tr>
<tr>
<td>Installing position of ramp</td>
<td>611</td>
<td>±1</td>
<td>±1</td>
<td></td>
</tr>
<tr>
<td>Deviation of ramp from vertical line</td>
<td>612</td>
<td>±1</td>
<td>±1</td>
<td></td>
</tr>
</tbody>
</table>

#### Section 3. HATCH COMINGS (SIDE ROLLING TYPE)

1. Dimension of hatch cover

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>6</td>
<td>±5</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Breadth (1 hatch)</td>
<td>6</td>
<td>±5</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Breadth (1 panel)</td>
<td>6</td>
<td>±4</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Height of cover</td>
<td>6</td>
<td>±3</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Difference between diagonals (1 panel)</td>
<td>6</td>
<td>±2</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Difference between diagonals (1 panel)</td>
<td>6</td>
<td>±2</td>
<td>Not Defined</td>
<td></td>
</tr>
</tbody>
</table>

2. Deflection of side, end and top plate

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection of side plate in the vertical direction</td>
<td>6</td>
<td>±3</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Deflection of end plate in the vertical direction</td>
<td>6</td>
<td>±3</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Bend of side plate in the transverse direction</td>
<td>6</td>
<td>±3</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Bend of end plate in the transverse direction</td>
<td>6</td>
<td>±3</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Deformation of top plate</td>
<td>6</td>
<td>±4</td>
<td>Not Defined</td>
<td></td>
</tr>
</tbody>
</table>

*Flatness of lower surface of hatch cover (1 panel) | 6 | ±3 | Not Defined | |
## I. HULL OUTFITTING

### 3. HATCH COVER (SIDE ROLLING TYPE)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Installing dimension of wheel</td>
<td>Span (between center lines)</td>
<td>611</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Installing height</td>
<td>612</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Installing pitch</td>
<td>613</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>4. Intermediate hinges and watertight construction</td>
<td>Height from base line to packing gutter</td>
<td>615</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth of packing gutter</td>
<td>616</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation between compression bar and packing</td>
<td>617</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compressed depth of packing</td>
<td>618</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation between top plates</td>
<td>619</td>
<td>±2</td>
<td>±4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation between end plates</td>
<td>620</td>
<td>±3</td>
<td>±4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clearance between hatch covers</td>
<td>621</td>
<td>±3</td>
<td>-5 to 10</td>
<td></td>
</tr>
<tr>
<td>5. Installing position of snap for quick acting cleat</td>
<td>Longitudinal deviation</td>
<td>622</td>
<td>±4</td>
<td>±6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vertical deviation</td>
<td>623</td>
<td>±4</td>
<td>±6</td>
<td></td>
</tr>
<tr>
<td>6. Clearance between hatch cover and hatch coaming</td>
<td>Touch piece type</td>
<td>624</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Directly touched type</td>
<td>625</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rest pad type</td>
<td>626</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
</tbody>
</table>

Note:
Every touchpiece of A or C type to be in touch with end and side girder of hatch cover or rest arm of hatch cover.

For type B, end and side girder of hatch cover to be in touch with the coaming, top plate of least one position in any 3 meters.

---

### 4. HATCH COMING (SIDE ROLLING TYPE)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of hatch coaming</td>
<td>Length</td>
<td>61</td>
<td>±5</td>
<td>±10</td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>62</td>
<td>±5</td>
<td>±10</td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals</td>
<td>63</td>
<td>≤10</td>
<td>≤15</td>
</tr>
</tbody>
</table>

Note:
- L = designed dimension
- L = actual dimension

* to be in accordance with hull specification.

FIG. A2.11 Hull Outfitting
# I. HULL OUTFITTING

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Deflection of horizontal stiffener (at installing position of compression bar)</td>
<td>End coating</td>
<td>63</td>
<td>±3</td>
<td>±5</td>
<td>* to be in accordance with hull specification.</td>
</tr>
<tr>
<td></td>
<td>Side coating</td>
<td>64</td>
<td>±5</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deflection in any one meter (at end and side coating)</td>
<td>65</td>
<td>±2</td>
<td>±3</td>
<td>l = Design dimension</td>
</tr>
<tr>
<td>3. Installing dimension of compression bar</td>
<td>Installing position</td>
<td>66</td>
<td>±3</td>
<td>±5</td>
<td>t = thickness of compression bar</td>
</tr>
<tr>
<td></td>
<td>Longitudinal and transverse deviation</td>
<td>67</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation from center line of cover packing</td>
<td>68</td>
<td>±5</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td>4. Installing dimension of roll</td>
<td>Installing position of roll</td>
<td>69</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level of roll top</td>
<td>610</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(from t)</td>
<td>611</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation between wheel center and jack center</td>
<td>612</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation between roll and flap</td>
<td>612</td>
<td>±1</td>
<td>±2</td>
<td></td>
</tr>
</tbody>
</table>

## Section 5. Hatch cover (Pontoons type for container ship)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of hatch cover</td>
<td>Length</td>
<td>61</td>
<td>±5</td>
<td>*</td>
<td>getField(acceptable tolerances for various support conditions shown follows:</td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>62</td>
<td>±5</td>
<td>*</td>
<td>getField(1: condition putting together. honttigh)</td>
</tr>
<tr>
<td></td>
<td>Height of cover</td>
<td>63</td>
<td>±3</td>
<td>*</td>
<td>getField(2: closed condition)</td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals</td>
<td>64</td>
<td>±2</td>
<td>*</td>
<td>getField(L, actual dimension to be measured by condition 2 at container mount on cover or pedestal)</td>
</tr>
<tr>
<td>2. Deflection of side, end and top plate</td>
<td>Deflection of side plate in the direction of up and down</td>
<td>65</td>
<td>±3</td>
<td>*</td>
<td>getField(1: not defined)</td>
</tr>
<tr>
<td></td>
<td>Deflection of end plate in the direction of up and down</td>
<td>66</td>
<td>±3</td>
<td>*</td>
<td>getField(2)</td>
</tr>
<tr>
<td></td>
<td>Bend of side plate in the direction of transverse</td>
<td>67</td>
<td>±3</td>
<td>*</td>
<td>getField(L, actual dimension to be measured by condition 2 at container mount on cover or pedestal)</td>
</tr>
<tr>
<td></td>
<td>Bend of end plate in the direction of transverse</td>
<td>68</td>
<td>±3</td>
<td>*</td>
<td>getField(L, actual dimension to be measured by condition 2 at container mount on cover or pedestal)</td>
</tr>
<tr>
<td></td>
<td>Deformation of top plate</td>
<td>69</td>
<td>±4</td>
<td>*</td>
<td>getField(L, actual dimension to be measured by condition 2 at container mount on cover or pedestal)</td>
</tr>
<tr>
<td></td>
<td>Flatness of under surface of cover</td>
<td>70</td>
<td>±3</td>
<td>*</td>
<td>getField(L, actual dimension to be measured by condition 2 at container mount on cover or pedestal)</td>
</tr>
</tbody>
</table>

*Fig. A2.12 Hull Outfitting*
## I. HULL OUTFITTING

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Water tightness</td>
<td>Height from base line to packing gutter</td>
<td>$\delta_1$</td>
<td>$\leq 1$</td>
<td>$\leq 2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breath of packing gutter</td>
<td>$\delta_2$</td>
<td>$\leq 1$</td>
<td>$\leq 2$</td>
<td></td>
</tr>
<tr>
<td>4. Clearance between hatch cover and hatch coaming</td>
<td>Touch piece type directly touched</td>
<td>$\delta_3$</td>
<td>$\leq 1$</td>
<td>$\leq 2$</td>
<td>Refer to note</td>
</tr>
<tr>
<td></td>
<td>Rest pad type</td>
<td>$\delta_4$</td>
<td>$\leq 3$</td>
<td>$\leq 5$</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
Every touchpiece of A or C type to be in touch with end and side girders of hatch cover or rest area of hatch cover.

For type B, end and side girders of hatch cover to be in touch with the coaming top plate at least one position in any 3 meters.

---

## II. HATCH COAMING (PONTOON TYPE FOR CONTAINER SHIP)

<table>
<thead>
<tr>
<th>Section</th>
<th><em>Length</em></th>
<th>$\delta_1$</th>
<th>$\leq 15$</th>
<th>$\leq 10$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Breadth</em></td>
<td>$\delta_2$</td>
<td>$\leq 5$</td>
<td>$\leq 10$</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Difference between diagonals</em></td>
<td>$\delta_3$</td>
<td>$\leq 5$</td>
<td>$\leq 15$</td>
<td></td>
</tr>
</tbody>
</table>

**2. Deflection of horizontal stiffener (at installing position of compression bar)**

|                              | *End coaming*                      | $\delta_4$ | $\leq 13$          | $\leq 5$           |         |
|                              | *Side coaming*                     | $\delta_5$ | $\leq 15$          | $\leq 8$           |         |
|                              | *Deflection in any one meter (at end and side coaming)* | $\delta_6$ | $\leq 2$           | $\leq 3$           |         |

**3. Installing dimension of compression bar**

|                              | *Installing position*              | $\delta_7$ | $\leq 15$          | $\leq 13$          |         |
|                              | *Longitudinal and transverse deviation* | $\delta_8$ | $\leq 13$          | $\leq 5$           |         |
|                              | *Deviation from center line of cover packing* | $\delta_9$ | $\leq 1$           | $\leq 2$           |         |

FIG. A2.13 Hull Outfitting
# I. HULL OUTFITTING

## Division
I-A WATER TIGHT STEEL HATCH COVER

## Section
1. MATCH COVER (FOLDING TYPE)

### Sub-section 1. Dimension of hatch cover

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limit (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (1 hatch)</td>
<td>5</td>
<td>±5</td>
<td>Not Defined</td>
<td></td>
</tr>
<tr>
<td>Length (1 panel)</td>
<td>6</td>
<td>±3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breath</td>
<td>7</td>
<td>±3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height of hatch cover</td>
<td>8</td>
<td>±3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference between diagonals (1 hatch)</td>
<td>9</td>
<td>±5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference between diagonals (1 panel)</td>
<td>10</td>
<td>±4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sub-section 2. Deflection of side end and top plate

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limit (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection of side plate in the vertical direction</td>
<td>5</td>
<td>±3</td>
<td></td>
<td>each cover is ranged and tightened</td>
</tr>
<tr>
<td>Deflection of end plate in the vertical direction</td>
<td>6</td>
<td>±3</td>
<td></td>
<td>L actual dimension</td>
</tr>
<tr>
<td>Bend of side plate in the transverse direction</td>
<td>7</td>
<td>±3</td>
<td></td>
<td>*indicates clearance between under surface of cover and surface table when putting on the surface table</td>
</tr>
<tr>
<td>Bend of end plate in the direction of transverse</td>
<td>8</td>
<td>±3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deformation of top plate</td>
<td>9</td>
<td>±4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flatness of transverse under surface of hatch cover (1 panel)</td>
<td>10</td>
<td>±3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sub-section 3. Installing dimension of wheel

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limit (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span (between center lines)</td>
<td>6</td>
<td>±2</td>
<td>±3</td>
</tr>
<tr>
<td>Installing height</td>
<td>7</td>
<td>±2</td>
<td>±3</td>
</tr>
<tr>
<td>Installing pitch</td>
<td>8</td>
<td>±2</td>
<td>±4</td>
</tr>
</tbody>
</table>

### Sub-section 4. Intermediate hedges and water tightness

<table>
<thead>
<tr>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limit (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height from base line to packing gutter</td>
<td>9</td>
<td>±1</td>
<td>±2</td>
<td>*thickness of compression bar</td>
</tr>
<tr>
<td>Breath of packing gutter</td>
<td>10</td>
<td>±1</td>
<td>±2</td>
<td>Compressed depth of packing surrounding hatch cover to be in accordance with this item.</td>
</tr>
<tr>
<td>Deviation between compression bar and packing</td>
<td>11</td>
<td>±5</td>
<td>±1</td>
<td>* not defined</td>
</tr>
<tr>
<td>Compressed depth of packing</td>
<td>12</td>
<td>±2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviation between top plates</td>
<td>13</td>
<td>±2</td>
<td>±4</td>
<td></td>
</tr>
<tr>
<td>Deviation between side plates</td>
<td>14</td>
<td>±2</td>
<td>±4</td>
<td></td>
</tr>
<tr>
<td>Clearance between hatch covers</td>
<td>15</td>
<td>±3</td>
<td>-5 to +10</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.14 Hull Outfitting
## I. HULL OUTFITTING

### Division

<table>
<thead>
<tr>
<th>Section</th>
<th>1. HATCH COVER (FOLDING TYPE)</th>
</tr>
</thead>
</table>

### Sub-section | Item | Figure | Standard Range (mm) | Tolerance Limits (mm) | Remarks |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Installing position of snap for quick acting cleat</td>
<td>Longitudinal deviation</td>
<td>$\delta_{21}$</td>
<td>$\pm 4$</td>
<td>$\pm 6$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vertical deviation</td>
<td>$\delta_{22}$</td>
<td>$\pm 4$</td>
<td>$\pm 6$</td>
<td></td>
</tr>
<tr>
<td>6. Clearance between hatch cover and hatch coaming</td>
<td>Touchpiece type</td>
<td>$\delta_{23}$</td>
<td>$\pm 1$</td>
<td>$\pm 2$</td>
<td>Refer to note</td>
</tr>
<tr>
<td></td>
<td>Directly of touched type</td>
<td>$\delta_{24}$</td>
<td>$\pm 3$</td>
<td>$\pm 5$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rest pad type</td>
<td>$\delta_{25}$</td>
<td>$\pm 1$</td>
<td>$\pm 2$</td>
<td></td>
</tr>
</tbody>
</table>

**Note**

Every touchpiece of A or C type to be in touch with end and and side girder of hatch cover or rest arm of hatch cover.

For type B, end and side girder of hatch cover to be in touch with the coaming top plate at least one postition in any 3 meters.

| 7. Installing dimension of intermediate and main hinge | Deviation between main hinge and baseline of hatch cover (longitudinal and vertical direction) | $\delta_{26}$ | $\pm 2$ | $\pm 3$ | |
| | Deviation between main hinge and baseline of hatch cover (longitudinal and vertical direction) | $\delta_{27}$ | $\pm 2$ | $\pm 3$ | |

| 8. Installing dimension of intermediate and main hinge | Deviation between eye plate for main cylinder and base line of hatch cover | $\delta_{28}$ | $\pm 2$ | $\pm 3$ | |

---

### Section

<table>
<thead>
<tr>
<th>2. HATCH COVER (FOLDING TYPE)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of hatch coaming</td>
<td>Length</td>
<td>$\delta_{1}$</td>
<td>$\pm 5$</td>
<td>$\pm 10$</td>
<td>* to be in accordance with hull specification.</td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>$\delta_{2}$</td>
<td>$\pm 5$</td>
<td>$\pm 10$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals</td>
<td>$L_{1} - L_{2}$</td>
<td>$\pm 10$</td>
<td>$\pm 15$</td>
<td>$L_{1}$ = designed dimension $L_{2}$ = actual dimension</td>
</tr>
</tbody>
</table>
## I. HULL OUTFITTING

### Division I-A WATER TIGHT STEEL HATCH COVER

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Deflection of horizontal stiffener (installing position of compression bar)</td>
<td>* End coating</td>
<td>63</td>
<td>±3</td>
<td>±5</td>
<td>* to be in accordance with hull specification.</td>
</tr>
<tr>
<td></td>
<td>* Side coating</td>
<td>64</td>
<td>±5</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Deflection in one meter (at end and side coating)</td>
<td>65</td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>3. Installing dimension of compression bar</td>
<td>Installing position</td>
<td>66</td>
<td>±3</td>
<td>±5</td>
<td>1 = thickness of compression bar</td>
</tr>
<tr>
<td></td>
<td>Longitudinal deviation</td>
<td>67</td>
<td>±3</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse deviation</td>
<td>68</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation from center line of cover packing</td>
<td>69</td>
<td>±5</td>
<td>±1</td>
<td></td>
</tr>
<tr>
<td>4. Installing dimension of guide rail</td>
<td>Installing position of rail</td>
<td>70</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation of ramp from vertical line</td>
<td>71</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
</tbody>
</table>

### Division I-B ENTRANCE DOOR AND HATCH

<table>
<thead>
<tr>
<th>Section</th>
<th>1. WATER TIGHT STEEL DOOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Door</td>
<td>Breadth</td>
</tr>
<tr>
<td></td>
<td>Height</td>
</tr>
<tr>
<td></td>
<td>Distortion</td>
</tr>
<tr>
<td></td>
<td>Straightness</td>
</tr>
<tr>
<td></td>
<td>Warp</td>
</tr>
<tr>
<td>2. Door coaming</td>
<td>Breadth</td>
</tr>
<tr>
<td></td>
<td>Height</td>
</tr>
<tr>
<td></td>
<td>Height of still</td>
</tr>
<tr>
<td></td>
<td>Distortion</td>
</tr>
<tr>
<td></td>
<td>Straightness</td>
</tr>
<tr>
<td></td>
<td>Warp</td>
</tr>
<tr>
<td>3. Port of cut steel wall</td>
<td>Breadth</td>
</tr>
<tr>
<td></td>
<td>Height</td>
</tr>
<tr>
<td></td>
<td>Height of still</td>
</tr>
<tr>
<td></td>
<td>Deformation</td>
</tr>
</tbody>
</table>

FIG. A2.16 Hull Outfitting
## I. HULL OUTFITTING

### Division

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hatch cover</td>
<td>Breadth 61</td>
<td><img src="image1" alt="Diagram" /></td>
<td>±3</td>
<td>±5</td>
<td>δ₃: distance between middle points of diagonals</td>
</tr>
<tr>
<td></td>
<td>Length 62</td>
<td></td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distortion 63</td>
<td></td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straightness 64</td>
<td></td>
<td>±1</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deformation (in any one meter) 65</td>
<td><img src="image2" alt="Diagram" /></td>
<td>±1</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>2. Hatch coaming</td>
<td>Breadth 66</td>
<td><img src="image3" alt="Diagram" /></td>
<td>±2</td>
<td>±5</td>
<td>δ₄: distance between middle points of diagonals</td>
</tr>
<tr>
<td></td>
<td>Length 67</td>
<td></td>
<td>±2</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height 68</td>
<td></td>
<td>0 - 6</td>
<td>0 - 20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distortion 69</td>
<td></td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straightness 610</td>
<td><img src="image4" alt="Diagram" /></td>
<td>±1</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>3. Port of cut deck plate (penetration type)</td>
<td>Breadth 611</td>
<td><img src="image5" alt="Diagram" /></td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length 612</td>
<td></td>
<td>±2</td>
<td>±3</td>
<td></td>
</tr>
<tr>
<td>4. Port of cut deck plate (non-penetration type)</td>
<td>Breadth 611</td>
<td><img src="image6" alt="Diagram" /></td>
<td>-3 - 2</td>
<td>-5 - 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length 612</td>
<td><img src="image7" alt="Diagram" /></td>
<td>-3 - 2</td>
<td>-5 - 3</td>
<td></td>
</tr>
<tr>
<td>5. Water tightness</td>
<td>Touch between gasket and coaming</td>
<td><img src="image8" alt="Diagram" /></td>
<td></td>
<td></td>
<td>B2L To be applied for steel water tight door and water tight steel small hatch. (Water tight door) B: Breadth of chalk clung on the gasket after tightening test. The test is to be carried out with thrusting chips to the middle of the wedges. (Water tight small hatch) B: Breadth of chalk clung on the gasket after tightening test. The test is to be carried out with thrusting chips to the middle of the wedges.</td>
</tr>
</tbody>
</table>
## I. HULL OUTFITTING

### I-C VENTILATOR AND SKYLIGHT

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water tightness</td>
<td>Contact between gasket and coaming</td>
<td>B2(\frac{3}{4})</td>
<td></td>
<td>Ventilation hole with wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wall louver</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Goose neck ventilator</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mushroom ventilator</td>
<td></td>
</tr>
</tbody>
</table>

### I. SKYLIGHT

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water tightness</td>
<td>Contact between gasket and coaming</td>
<td>B2(\frac{3}{2})</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### I-D CARGO LOADING APPARATUS

#### I. WELDING FABRICATED BOOM

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Derrick boom</td>
<td>Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bending</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diameter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permissible out of roundness of cylindrical shell at installing position of base assemblies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Derrick boom and assemblies</td>
<td>Distortion between assemblies on base and assemblies on top</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

FIG. A2.18 Hull Outfitting
# I. HULL OUTFITTING

## Division
- I-E CONTAINER LASHING DEVICES

## Section 1. CONTAINER LASHING FITTING

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: 20' Container fitting</td>
<td>Length</td>
<td>$\delta_1$</td>
<td>13</td>
<td>14</td>
<td>○ and □ indicate acceptable tolerances for various support conditions shown follows: ○: condition putting together, nontight; □: closed condition L = Specified dimension</td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>$\delta_2$</td>
<td>12</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference of height at cross section of diagonals</td>
<td>$\delta_3$</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals</td>
<td>$\delta_4$</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2: 40' Container fitting</td>
<td>Length</td>
<td>$\delta_1$</td>
<td>13</td>
<td>15</td>
<td>L = actual dimension to be measured by condition ○ at container mount on cover or pedestal.</td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>$\delta_2$</td>
<td>12</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference of height at cross section of diagonals</td>
<td>$\delta_3$</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals</td>
<td>$\delta_4$</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>3: Clearance between cell guide and container</td>
<td>Length</td>
<td>$\delta_1$</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>$\delta_2$</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A2.19 Hull Outfitting**
## I. HULL OUTFITTING

### Division

**I-F MOBILE DECK, RAMP WAY, ETC.**

### Section 1

**HOISTABLE DECK (LIFTABLE DECK)**

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of deck</td>
<td>Length</td>
<td>6.1</td>
<td>±5</td>
<td>±8</td>
<td><em>l</em> designed dimension</td>
</tr>
<tr>
<td></td>
<td>Breadth</td>
<td>6.2</td>
<td>±5</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height</td>
<td>6.3</td>
<td>±3</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference between diagonals</td>
<td>6.4</td>
<td>±8</td>
<td>±10</td>
<td></td>
</tr>
<tr>
<td>2. Distortion of deck</td>
<td>Deflection of deck</td>
<td>6.5</td>
<td>-5</td>
<td>+10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distortion of deck</td>
<td>6.6</td>
<td>±5</td>
<td>+10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deviation of deck from deck level</td>
<td>6.7</td>
<td>-2</td>
<td>+5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Clearance between decks</td>
<td>Difference in level between movable decks</td>
<td>6.10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.11</td>
<td>±5</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.12</td>
<td>±10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Height between decks</td>
<td>Height between fixed deck and movable deck</td>
<td>6.13</td>
<td>±20</td>
<td>-0</td>
<td><em>l</em> designed dimension</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.14</td>
<td>±20</td>
<td>-0</td>
<td></td>
</tr>
<tr>
<td>5. Guiderail</td>
<td>Deviation of guiderail from vertical line</td>
<td>6.15</td>
<td>5</td>
<td></td>
<td>δ15: deviation from vertical line between one deck, spans.</td>
</tr>
<tr>
<td>6. Clearance between pillar and movable deck</td>
<td>Deviation of guiderail from vertical line</td>
<td>6.16</td>
<td>±10</td>
<td></td>
<td><em>l</em> designed dimension</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.17</td>
<td>±10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Clearance between guiderail and guide piece</td>
<td>Clearance between guiderail and guide piece</td>
<td>6.18</td>
<td>+8</td>
<td>-0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.19</td>
<td>+8</td>
<td>-0</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.20 Hull Outfitting
# I. HULL OUTFITTING

**Division**: I-F Movable Deck, Ramp Way, Etc.

**Section 2**: Stern Ramp (Including Ramp Door)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of ramp</td>
<td>Breadth (lower part)</td>
<td>δ₁</td>
<td>5</td>
<td>8</td>
<td>Designed dimension</td>
</tr>
<tr>
<td></td>
<td>Breadth (upper part)</td>
<td>δ₂</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length (SEC I)</td>
<td>δ₃</td>
<td>5</td>
<td>8</td>
<td>CL₁ : center of main hinges</td>
</tr>
<tr>
<td></td>
<td>Length (SEC II)</td>
<td>δ₄</td>
<td>5</td>
<td>8</td>
<td>CL₂ : center of interchange</td>
</tr>
<tr>
<td></td>
<td>Length (TOTAL)</td>
<td>δ₅</td>
<td>10</td>
<td>16</td>
<td>CL₃ : center of flap hinges</td>
</tr>
<tr>
<td>2. Position of hinges</td>
<td>Distance between main hinges</td>
<td>δ₆</td>
<td>14</td>
<td></td>
<td>L + δ₁ = ρ₀ - δ₀</td>
</tr>
<tr>
<td></td>
<td>Distance between the center of hinges</td>
<td>δ₇</td>
<td>14</td>
<td></td>
<td>L + δ₁ = ρ₀ + δ₀ - δ₀</td>
</tr>
<tr>
<td></td>
<td>Distance between inter-hinge</td>
<td>δ₈</td>
<td>5</td>
<td></td>
<td>δ₁₂, δ₁₃: to be measured after erection</td>
</tr>
<tr>
<td>3. Dimension of ramp door</td>
<td>Longitudinal distance between compression bars</td>
<td>δ₁₀</td>
<td>5</td>
<td></td>
<td>δ₁₂, δ₁₃: actual distance</td>
</tr>
<tr>
<td></td>
<td>Transverse distance between compression bars</td>
<td>δ₁₁</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference between diagonal distances of compression bar</td>
<td>δ₁₂, δ₁₃</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Distortion of ramp</td>
<td>Longitudinal distortion</td>
<td>δ₁₄</td>
<td>5</td>
<td></td>
<td>δ₁₄, δ₁₅: Distortion of top plate on girders</td>
</tr>
<tr>
<td></td>
<td>Transverse distortion</td>
<td>δ₁₅</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Clearance etc. in way of tightening part</td>
<td>Deviation of the position of compression bar from the centerline of packing</td>
<td>δ₁₆</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clearance between the packing groove and the top plate of ramp door</td>
<td>δ₁₇</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A2.21 Hull Outfitting**
## I. HULL OUTFITTING

### Section 3: Midship Ramp (Including Ramp Door)

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of ramp</td>
<td>Breadth (lower part)</td>
<td>δ₁</td>
<td>±5</td>
<td>±8</td>
<td>t-dimension</td>
</tr>
<tr>
<td></td>
<td>Breadth (upper part)</td>
<td>δ₂</td>
<td>±5</td>
<td>±8</td>
<td>CL₁ : center of main hinges</td>
</tr>
<tr>
<td></td>
<td>Length (ramp)</td>
<td>δ₃</td>
<td>±5</td>
<td>±8</td>
<td>CL₂ : center of flap hinges</td>
</tr>
<tr>
<td></td>
<td>Length (flap)</td>
<td>δ₄</td>
<td>±5</td>
<td>±8</td>
<td></td>
</tr>
<tr>
<td>2. Dimension and position of hinges</td>
<td>Distance between main hinges</td>
<td>δ₅</td>
<td>±5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breadth of lifting area</td>
<td>δ₆</td>
<td>±2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Dimension of ramp door</td>
<td>Longitudinal distance between compression bars</td>
<td>δ₇</td>
<td>±5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse distance between compression bars</td>
<td>δ₈</td>
<td>±5</td>
<td>δ₉, δ₁₀: actual distance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference between diagonal distances of compression bar</td>
<td>δ₉, δ₁₀</td>
<td>±8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Distortion of ramp</td>
<td>Longitudinal distortion</td>
<td>δ₁₁</td>
<td>±5</td>
<td>δ₁₁, δ₁₂: Distortion of top plate on girders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse distortion</td>
<td>δ₁₂</td>
<td>±5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Clearance etc. in way of tightening part</td>
<td>Deviation of the position of compression bar from the centerline of packing</td>
<td>δ₁₃</td>
<td>±5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clearance between the packing gudgeon and the top plate of ramp door</td>
<td>δ₁₄</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.22 Hull Outfitting
## I. HULL OUTFITTING

### Division
I-F MOVABLE DECK, RAMP WAY, ETC.

### Section 4
BULKHEAD DOOR/COAMING

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dimension of door</td>
<td>breadth</td>
<td></td>
<td>5</td>
<td>5 ≡</td>
<td>designed dimension</td>
</tr>
<tr>
<td></td>
<td>height</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>depth</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>difference between diagonal distances</td>
<td></td>
<td>18</td>
<td>14</td>
<td>actual dimension</td>
</tr>
<tr>
<td>2. Position of fittings</td>
<td>height of the center line of wheel</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>position of cleat</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>position of stopping device</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3. Distortion of door</td>
<td>distortion (transverse direction)</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>distortion (vertical direction)</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4. Dimension of coaming</td>
<td>breadth</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>height</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>depth</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>difference between diagonal distances</td>
<td></td>
<td>18</td>
<td>14</td>
<td>actual dimension</td>
</tr>
<tr>
<td>5. Position of roll</td>
<td>distance from the bulkhead to the center of guide rail</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6. Distortion of coaming</td>
<td>deflection (transverse direction)</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deflection (vertical direction)</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>distortion (transverse direction)</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>distortion (vertical direction)</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Clearance between deck and back plate of door packing</td>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Gap between the corner of tight bar and packing end</td>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A2.23 Hull Outfitting
### II. WOODWORK

**Division** | II-A ACCOMMODATION SPACE  
---|---
**Section 1** | DOOR AND DOOR FRAME  
**Sub-section** | Item  
1. Clearance between door and door frame  
Between wooden door and door frame  
Between steel door and door frame  
**Figure**  
**Standard Range (mm)** | **Tolerance Limits (mm)** | Remarks  
---|---|---
| | $S_2$ | $S_3$ |  
| | $S_2$ | $S_3$ |  

---

**Section 2** | DIVISIONAL WALL  
1. Fitting of division wall  
Deviation  
**Figure**  
**Standard Range (mm)** | **Tolerance Limits (mm)** | Remarks  
---|---|---
$S_5$ | $S_8$ |  

---

**Section 3** | CEILING  
1. Ceiling clear height  
Short of ceiling clear height (clear height)  
**Figure**  
**Standard Range (mm)** | Remarks  
---|---  
$S_{10}$ | To be defined by planned dimension  

---

**Section 4** | DETAIL OF DIVISIONAL PARTS  
1. Joint piece of woodwork  
Relation between wooden parts and screw hole  
Deviation from marking line  
**Figure**  
**Standard Range (mm)** | **Tolerance Limits (mm)** | Remarks  
---|---|---  
$S_5$ | $S_5$ |  

---

FIG. A2.24 Woodwork
## II. WOODWORK

### II-A ACCOMMODATION

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Alignment of plywood joint</td>
<td>A joiner (plywood with the last coat of paint)</td>
<td>δ₂</td>
<td>≤0.5</td>
<td>≤1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A joiner (To be veneered)</td>
<td>δ₃</td>
<td>≤0.3</td>
<td>≤0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No joiner (To be veneered)</td>
<td>δ₄</td>
<td>≤0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A joiner with joint pieces (To be veneered)</td>
<td>δ₅</td>
<td>≤0.5</td>
<td>≤1</td>
<td></td>
</tr>
<tr>
<td>3. Clearance of plywood joint</td>
<td>Plywood with the last coat of paint</td>
<td>δ₆</td>
<td>≤0.3</td>
<td>≤1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Without joint pieces (To be veneered)</td>
<td>δ₇</td>
<td>≤0.3</td>
<td>≤0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>With joint pieces (To be veneered)</td>
<td>δ₈</td>
<td>≤1</td>
<td>≤2</td>
<td></td>
</tr>
<tr>
<td>4. Penetrations of wooden wall</td>
<td>Fireproof bulkhead (Clearance and lap length)</td>
<td>δ₉</td>
<td>≤2</td>
<td>≤2.5</td>
<td>≥25</td>
</tr>
<tr>
<td>5. Steel panel</td>
<td>Deviation between upper and lower pieces</td>
<td>δ₁₀</td>
<td>≤5</td>
<td>≤8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alignment of joint</td>
<td>δ₁₁</td>
<td>≤0.5</td>
<td>≤1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gap of joint</td>
<td>δ₁₂</td>
<td>≤0.5</td>
<td>≤1</td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A2.25 Woodwork**

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## II. WOODWORK

### Division II-A ACCOMMODATION

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Deck composition</td>
<td>Flatness of deck composition</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>≤5</td>
<td></td>
<td>Depth of δ1 in two meters.</td>
</tr>
<tr>
<td>2. Deck covering</td>
<td>Flatness of deck covering</td>
<td><img src="image2.png" alt="Diagram" /></td>
<td>≤5</td>
<td>Ditto</td>
<td></td>
</tr>
</tbody>
</table>

### Division II-B DECK COMPARTMENT

#### Section 1 ON DECK

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Deck planking</td>
<td>Gap between deck planking and steel deck</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>≤7</td>
<td>≤9</td>
<td>Distortion of steel deck is based on quality standard for hull. Deck planking is based on quality standard for bare steel parts.</td>
</tr>
</tbody>
</table>

#### Section 2 IN HOLD

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Clearance between sparrings and cleat</td>
<td>Horizontal</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td>≤6</td>
<td>≤10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td>≤6</td>
<td>≤10</td>
<td></td>
</tr>
<tr>
<td>2. Location of cleat</td>
<td>Deviation of sparrings from frame</td>
<td><img src="image6.png" alt="Diagram" /></td>
<td>10 ≤ a</td>
<td>5 ≤ a</td>
<td>Fitting accuracy of cleat is defined as installed. In case where it is impossible to comply with the standard, due to form of frames, sparrings is to be divided as appropriate.</td>
</tr>
</tbody>
</table>

#### Section 3 THE COLD STORAGE SPACES

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Not defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Door</td>
<td>Air tightness of door</td>
<td>Not defined</td>
</tr>
</tbody>
</table>

To be checked by chalk test. No measurable frost outside the cold storage spaces under refrigerating test. In case where it frosts, blow air from the outside and check with leakage of air with a candle or a hose stick in the cold storage space.

---

FIG. A2.26 Woodwork
# IV. MACHINERY

## Division
**IV-A Rudder**

## Section
**1. Rudder Plate and Rudder Stock**

### Sub-section
- **1. Reamer**
  - **Dimension of reamer bolt hole Cylindrical (D1, D2)**
  - **Dimension of reamer bolt hole Roundness Cylindrical (d1, d2)**
  - **Interference of reamer bolt d-b**

### Tolerance Standards

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension of reamer bolt hole Cylindrical</td>
<td></td>
<td>±0.01 ±0.02</td>
<td>Diameter of bolt</td>
</tr>
<tr>
<td>Dimension of reamer bolt hole Roundness</td>
<td></td>
<td>±0.01 ±0.02</td>
<td>Diameter of hole</td>
</tr>
<tr>
<td>Interference of reamer bolt d-b</td>
<td>0.005 ±0.015</td>
<td>&gt;0</td>
<td></td>
</tr>
</tbody>
</table>

### 2. Join
- **Facing surface area between rudder plate and rudder stock**
  - **Deviation from the center line of rudder and rudder stock after connection δ1**
  - **Length of rudder plate and rudder stock after connection δ2**
  - **Length of rudder plate δ3**
  - **Total length δ2-δ3**
  - **Gap between rudder plate and rudder stock after connection δ4**

### Tolerance Standards

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation from the center line of rudder and rudder stock after connection δ1</td>
<td>±0.3</td>
<td>±0.5</td>
<td>Both longitudinal and transverse deviations are to comply with this standard</td>
</tr>
<tr>
<td>Length of rudder plate and rudder stock after connection δ2</td>
<td>±2</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td>Length of rudder plate δ3</td>
<td>±4</td>
<td>±4</td>
<td></td>
</tr>
<tr>
<td>Total length δ2-δ3</td>
<td>±5</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td>Gap between rudder plate and rudder stock after connection δ4</td>
<td>&lt;0.03</td>
<td>±0.03</td>
<td>After tightening of reamer bolt</td>
</tr>
</tbody>
</table>

### 3. Sleeve of Rudder Stock
- **Interference for sleeve of rudder stock (S U S, B C)**

### Tolerance Standards

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interference for sleeve of rudder stock</td>
<td>d4-d3</td>
<td>(5-10)d4</td>
<td>d4: outside dia. of rudder stock of sleeve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10-20)d4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10,000</td>
<td></td>
</tr>
</tbody>
</table>

## Section 2. Pintle and Gudgeon Bushing

### 1. Pintle
- **Facing surface area between pintle and taper of rudder plate**

### Tolerance Standards

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facing surface area between pintle and taper of rudder plate</td>
<td>&gt;60%</td>
<td>±0.01</td>
<td>*not defined</td>
</tr>
</tbody>
</table>

### 2. Gudgeon Bushing
- **Interference of gudgeon bushing (B C, SUS, Synthetic resin)**

### Tolerance Standards

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interference of gudgeon bushing</td>
<td>d4-d3</td>
<td>0-0.05</td>
<td>*not defined</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### IV. MACHINERY

#### Division IV-A Rudder

**3. Stern Frame**

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gudgeon center line</td>
<td>Alignment of center line for rudder carriers, upper &amp; lower gudgeons after boring, or after casing, eccentric bushing</td>
<td>δ₁</td>
<td>≤0.3</td>
<td>≤0.5</td>
<td>Both longitudinal and transverse deviations are to comply to this standard</td>
</tr>
</tbody>
</table>

#### Section 4. Rudder tiller

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rudder stock and tiller</td>
<td>Interference of rudder stock and tiller</td>
<td>Rudder tiller</td>
<td>0.005 -0.015</td>
<td>&gt;0</td>
<td></td>
</tr>
<tr>
<td>2. Rudder stock and tiller with taper</td>
<td>Facing surface area between rudder stock and tiller</td>
<td>Fastening clearance of taper key</td>
<td>&gt;60%</td>
<td>*</td>
<td>not defined</td>
</tr>
</tbody>
</table>

#### Section 5. Rudder carrier and stuffing box

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Installation</td>
<td>Facing surface area of liner Gap between rudder carrier and liner</td>
<td>Distance place</td>
<td>&gt;50%</td>
<td>*</td>
<td>not defined</td>
</tr>
</tbody>
</table>

#### Division IV-B Steering engine

**1. Ram cylinder type**

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rammer bolt</td>
<td>Interference</td>
<td>d-D</td>
<td>0.01</td>
<td>&gt;0</td>
<td>d, dia. of bolt D, dia of hole</td>
</tr>
<tr>
<td>2. Installation of liner (Top liner, Chock liner)</td>
<td>Clearance</td>
<td></td>
<td>&lt;0.06</td>
<td>*</td>
<td>not defined</td>
</tr>
<tr>
<td>3. Level and torsion of ram cylinder</td>
<td>Level and torsion</td>
<td></td>
<td>7°50'</td>
<td>Within 75% of clearance of ram cylinder</td>
<td></td>
</tr>
</tbody>
</table>

---

FIG. A2.28 Machinery
# IV. MACHINERY

## Section 1. Ram cylinder type

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Alignment coupling center of hydraulic pump after installation</td>
<td>Inclination of the surface</td>
<td>$</td>
<td>T_1-T_2</td>
<td>$</td>
<td>≤0.07</td>
</tr>
<tr>
<td></td>
<td>Concentricity</td>
<td>Dialguage</td>
<td>≤0.05</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

## Section 2. Rotary vane type

| 1 Taper area between rudder stock and boss on steering engine | Facing surface area | 260% | * | *not defined |
| | | | | | |
| 2 Interference mark on nut at the top of the rudder stock | Push up travel | 0.6 | -1.0 | * | Length of indentation is according to the maker standard. *not defined |

## Section 3. Alignment of coupling center of hydraulic pump after installation

| 2 | Inclination of the surface | $|T_1-T_2|$ | ≤0.07 | * | In case of solid coupling to be measured by means of dial guage. See left sketch |
| | Concentricity | Dialguage | ≤0.05 | * | |

## Division IV-C Deck machine

## Section 1. Installation of machine seat

<table>
<thead>
<tr>
<th>Clearance between seat and machine</th>
<th>A class</th>
<th>B class</th>
<th>C class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.06</td>
<td>&lt;0.10</td>
<td>A class: deck crane and cargo gear</td>
</tr>
<tr>
<td></td>
<td>&lt;0.10</td>
<td>&lt;0.20</td>
<td>B class: pump</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>C class: miscellaneous winch and davit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A B C class to be measured before tightening *not defined</td>
</tr>
</tbody>
</table>

FIG. A2.29 Machinery
## IV. MACHINERY

### Division IV-C Deck machine

#### Section 1. Installation of machine seat

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Alignment of coupling center</td>
<td>Inclination of the surface</td>
<td>( T_1 - T_2 )</td>
<td>( \leq 0.07 )</td>
<td>• In case of solid coupling to be measured by means of dial gauge. See sketch.</td>
</tr>
<tr>
<td></td>
<td>Concentricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diaolgauge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Alignment of shaft center</td>
<td>IC-DL</td>
<td>( \frac{1}{2} )</td>
<td>( \leq 0.05 )</td>
<td>• A class *not defined</td>
</tr>
</tbody>
</table>

### Division IV-D Deck crane

#### Section 1. Traveling type (include traveling type hopper)

<table>
<thead>
<tr>
<th>Lifting roll</th>
<th>Distance between center of the rolls (one side type)</th>
<th>( \leq 5 )</th>
<th>•</th>
<th>•not defined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance between center of the rolls (both side type)</td>
<td>( \leq 5 )</td>
<td>•</td>
<td>•not defined</td>
</tr>
<tr>
<td></td>
<td>Horizontal line of roll (for optional 10m)</td>
<td>( \leq 5 )</td>
<td>•</td>
<td>Standard per meter</td>
</tr>
<tr>
<td></td>
<td>Vertical line of roll (for optional 10m)</td>
<td>( \leq 5 )</td>
<td>•</td>
<td>Standard per meter</td>
</tr>
<tr>
<td></td>
<td>Slope of roll (for optional 10m)</td>
<td>( \leq 0.000 )</td>
<td>•</td>
<td>Standard per meter</td>
</tr>
<tr>
<td></td>
<td>Plane of roll (for optional 10m)</td>
<td>( \leq 0.000 )</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inclination of roll</td>
<td>( \leq 0.000 )</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference of height between port and stbd</td>
<td>( \leq 8 )</td>
<td>•</td>
<td>To be measured at each 5m</td>
</tr>
</tbody>
</table>

**FIG. A.2.30 Machinery**
### IV. MACHINERY

**Division**: IV-D Deck crane

**Section 2. Fixed type**

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Item</th>
<th>Figure</th>
<th>Standard Range (mm)</th>
<th>Tolerance Limits (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Installation of post</td>
<td>Plane of flange 16,1</td>
<td>$\delta_1$</td>
<td>0.4</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference of bolt hole on flange 16,1</td>
<td>$\delta_2$</td>
<td>0.6</td>
<td>*</td>
<td>Difference for diameter *not defined</td>
</tr>
</tbody>
</table>

**Division IV-E Side thruster**

**Section 1. Side thruster**

| | | | | | |
| Center of coupling | Clearance between tube and blade $\delta_1$ | $\delta_1$ | 50/1000 | * | Universal coupling type *not defined |
| 2 Deformation of tube | Clearance between tube and blade $\delta_1$ | $\delta_1$ | $\geq \frac{D}{600}$ | * | *not defined |

**FIG. A2.31 Machinery**
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A3.1
3. Type of cargo
A3.1
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A3.1
5. Outfitting
A3.1
6. Paint to be used
A3.1
7. Dry film thickness
A3.1
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A3.1
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A3.8
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57. Gas concentration of solvent
A3.8
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### A3.2 Introduction

A3.2.1 This practice for coatings addresses those aspects of coating application inherent in achieving finished product quality that can be measured and warranted as meeting acceptable criteria. Because of the nature of coating systems, in which preparation and methodology directly affect finished quality, this practice contains information about processes and application practices, as well as, pass/fail criteria of the end product. It should be acknowledged that measuring finished coating attributes cannot determine that good application practices were followed and, therefore, cannot be used as a sole means of warranting the finished quality of the coating.

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Prerequisites</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type of Vessel</td>
<td>Commercial and Military</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tank Coating Area</td>
<td>No Limitation</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Type of cargo</td>
<td>Products identified in the specification section.</td>
<td>Refer to ship’s specification</td>
</tr>
<tr>
<td>4</td>
<td>Tank anodes</td>
<td>In accordance with ship’s specifications in Water Ballast Tanks and Slop Retention Tank.</td>
<td>Refer to ship’s specification. Refer to Fig. A3.9 (Explanation).</td>
</tr>
<tr>
<td>5</td>
<td>Outfitting</td>
<td>In the case of steel, painting is similar to the surrounding area. Paint shall not be applied to woodwork, polished fittings, gaskets, packing, anodes, non-ferrous material, or other non-corrosive metals and any other surface or fittings and equipment where paint could obstruct their proper function.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Paint to be used</td>
<td>As specified by owner. Coatings shall be lead free, chromate free, asbestos free, cadmium free and comply with applicable Federal, State and local Regulations.</td>
<td>Refer to ship’s specification</td>
</tr>
<tr>
<td>7</td>
<td>Dry film thickness</td>
<td>Refer to ship’s specification and manufacturer’s recommendations.</td>
<td>Refer to Fig. A3.9 (Explanation).</td>
</tr>
<tr>
<td>8</td>
<td>Shop primer</td>
<td>After primary surface preparation, one (1) coat of inorganic zinc silicate type shop primer will be applied in accordance with the paint manufacturer’s recommendation, for structural steel not coated with inorganic zinc silicate type shop primer builder shall blast to SSPC-SP 10 and apply first coat of specified system, subject to owner approval. Surface profile to comply with ship’s specification.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Holding coat</td>
<td>As determined by builder with consideration to paint manufacturer’s recommendation.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Painting Process</td>
<td>Block unit through completion.</td>
<td>Refer to Fig. A3.9 (Explanation).</td>
</tr>
</tbody>
</table>

FIG. A3.1 General
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Process Standard</th>
<th>Judgment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Free edge In Immersion Service Areas To Be Coated</td>
<td>(1) Break 90 degree edges 1 mm minimum. (2) In general, rolled angle edges, bulb flats, etc. (including flat bars) are to be left untreated.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Spatter In Immersion Service Areas To Be Coated</td>
<td>(1) For spatter observed before blasting: (a) Remove with a chipping hammer, scraper, etc. (b) For spatter not easily removable with a scraper, etc. Use grinder or disc. Note: It is the intent of this standard that all spatter is to be removed before surface prep. Any remaining or additional spatter observed after surface prep shall be removed in accordance with (1(a) and 1(b).</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Undercut</td>
<td>Undercut to a depth exceeding 1.6mm and a width smaller than the depth is to be repaired by grinding. If a sharp edge exists with a crest exceeding 3mm grind until irregularity is less than 3mm.</td>
<td>Visual</td>
<td>Refer to Fig. A3.10 (Explan.)</td>
</tr>
<tr>
<td>14</td>
<td>Surface damage</td>
<td>Surface damage, pitting, break-off marks to depths exceeding 1 mm are to be repaired by welding or grinding</td>
<td>Visual</td>
<td>Refer to Fig. A3.10 (Explan.)</td>
</tr>
<tr>
<td>15</td>
<td>Manual welding bead</td>
<td>Weld beads with surface irregularities exceeding 3 mm or with a sharp crest are to be ground until the irregularity is less than 3 mm.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Automatic welding bead</td>
<td>In general, no specific treatment is required.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Overlap welding bead</td>
<td>Overlapping weld beads that create sharp notches are to be repaired as per item No. 13, “Undercut.”</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Welding arc strike</td>
<td>Same as Item No. 12, “Spatter”, and Item No. 14, “Surface Damage.”</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Gas cut surface</td>
<td>Gas cut surfaces are to be ground as follows. (a) Except where hull strength considerations require a smooth finish, notches shall be ground to less than 2mm. (b) Gas slag produced during cutting is to be treated according to item 11, “Free Edge.” Treatment to be accomplished before blasting.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Lifting lugs</td>
<td>Where a lifting lug is partially removed by cutting the pad-eye portion off per page 17 of the Hull volume, the remaining stub and surrounding area is to be treated according to item No. 11 “Free Edge”, item No. 15 “Manual welding bead”, and item No. 19 “Gas cut surface”.</td>
<td>Visual</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A3.2 Presurface Preparation Standards
FIG. A3.2 Presurface Preparation Standards (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Process Standard</th>
<th>Judgment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Solvent Cleaning</td>
<td>Refer to ship’s specification</td>
<td>Visual</td>
<td>Standards</td>
</tr>
<tr>
<td>27</td>
<td>Mechanical Cleaning</td>
<td>Refer to ship’s specification</td>
<td>Visual</td>
<td>Standards</td>
</tr>
<tr>
<td>28</td>
<td>Abrasive Blast Cleaning And Surface Profile</td>
<td>Refer to ship’s specification</td>
<td>Visual</td>
<td>Standards</td>
</tr>
<tr>
<td>29</td>
<td>Water Jetting</td>
<td>Refer to ship’s specification</td>
<td>Visual</td>
<td>Standards</td>
</tr>
<tr>
<td>30</td>
<td>Abrasives</td>
<td>Refer to ship’s specification</td>
<td>Written</td>
<td>Standards</td>
</tr>
<tr>
<td>31</td>
<td>Repairs to Shop Primed Surfaces</td>
<td>Refer to ship’s specification</td>
<td>Visual</td>
<td>Standards</td>
</tr>
</tbody>
</table>

FIG. A3.3 Surface Preparation Standards

FIG. A3.4 Coating Standards

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Process Standard</th>
<th>Judgment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Stripe Coating Tanks</td>
<td>To achieve the specified DFT, stripe coats shall be applied to: edges of small holes, corners of other flame burned edges, free edges of structural members, and rough welding seams.</td>
<td>Visual</td>
<td>Refer to Fig. A3.12 (Explanations)</td>
</tr>
<tr>
<td>33</td>
<td>Overall coat</td>
<td>When more than one coat is specified, subsequent coats shall not be applied until preceding coat has sufficiently cured/dried in accordance with paint manufacturer’s recommendation.</td>
<td>Wet gauge and Visual</td>
<td></td>
</tr>
</tbody>
</table>

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### FIG. A3.5 Coating Repair Standards

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Process standard</th>
<th>Judgment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Sagging</td>
<td>Sagging with a height of 2 mm or more is to be repaired in accordance with the paint manufacturer’s recommendations.</td>
<td>Visual</td>
<td>Refer to Fig. A3.13 (Explanations)</td>
</tr>
<tr>
<td>35</td>
<td>Spray dust</td>
<td>Dry spray, over spray, and spray dust is to be removed before painting in accordance with the manufacturer’s recommendations.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Foreign matter</td>
<td>Foreign matter in the paint film shall be removed. Damaged film is to be repaired in accordance with the manufacturer’s recommendations.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Crater, pinholes and bubbles</td>
<td>Defects are to be repaired in accordance with the manufacturer’s recommendations.</td>
<td>Visual</td>
<td>Refer to Fig. A3.13 (Explanations)</td>
</tr>
<tr>
<td>38</td>
<td>Blushing</td>
<td>Excepting the final coat film, visible blushing on the film surface is to be repaired in accordance with the manufacturer’s recommendations.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Mechanical damage</td>
<td>Touch up is to be equivalent to the original specification, unless otherwise noted in the Painting Plan.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Insufficient film thickness</td>
<td>Areas with insufficient film thickness are to be repaired in accordance with the manufacturer’s recommendations.</td>
<td>Visual/Dry Film Gage</td>
<td>Refer to Fig. A3.14 (Explanations)</td>
</tr>
</tbody>
</table>

### FIG. A3.6 Film Thickness Measurement Standards

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Process standard</th>
<th>Judgment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>Film thickness measurement of tank plate</td>
<td>Film thickness to be measured for every five square meters for flat panels or corrugated bulkheads. Film thickness is to be measured at two (2) points in each panel of plating bounded by transverse and longitudinal members. (Note: this excludes panel breaker, or panel stiffeners)</td>
<td>Micro tester or electromagnetic film thickness gauge</td>
<td>Refer to Fig. A3.14 (Explanations)</td>
</tr>
<tr>
<td>42</td>
<td>Film thickness measurement of tank longitudinal members</td>
<td>Film thickness to be measured at two points between transverse members on each side of web and face plates (Note: this excludes panel breakers and panel stiffeners)</td>
<td>Micro tester or electromagnetic film thickness gauge</td>
<td>Refer to Fig. A3.14 (Explanations)</td>
</tr>
<tr>
<td>43</td>
<td>Film thickness measurement of tank transverse members</td>
<td>Film thickness to be measured at three points between longitudinal girders or bulkhead on each side of web and face plates.</td>
<td>Micro tester or electromagnetic film thickness gauge</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Item</td>
<td>Process standard</td>
<td>Judgment</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>---------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>44</td>
<td>Temperature (During painting, and drying)</td>
<td>Steel and air temperatures are to be in accordance with the paint manufacturer’s recommendations.</td>
<td>Measure with a thermometer</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Humidity (During painting, and initial drying)</td>
<td>Paint shall not be applied during periods of rain, snow, fog or mist in the open air or when ambient relative humidity exceeds manufacturer recommendation.</td>
<td>Measure with a hygrometer. Measure with a surface thermometer</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Ventilation (Immediately before blasting to paint)</td>
<td>Air change rate to be two times per hour, or more as directed by the manufacturer’s product data sheet.</td>
<td>Check ventilating requirement</td>
<td>Refer to Fig. A3.15 (Explanations)</td>
</tr>
<tr>
<td>47</td>
<td>Ventilation (During paint drying)</td>
<td>Air change rate to be five times per hour or more. Dehumidifying capacity to be according to ventilation requirements. If the external air humidity is above 85%, air change rate may be decreased to the capacity of the dehumidifier.</td>
<td>Check ventilating requirement</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Erection of scaffolding</td>
<td>Make sure that scaffolding does not interfere with painting, ventilation, illumination, blasting and inspection (builder shall attempt to maintain a 150 mm clearance wherever possible). If not possible (to maintain the 150 mm clearance), the Owner shall be informed of the particular area and review during the scaffolding inspection.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Removal of scaffolding</td>
<td>Care must be taken not to damage the film.</td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Illumination</td>
<td>Effective illumination to be provided to ensure proper inspection of the blast and coated surface is achieved.</td>
<td>Visual</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A3.7 Environmental Painting Standards
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Standard</th>
<th>Control</th>
<th>Owner</th>
<th>Shipy ard</th>
<th>Paint Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>Pre-Surface Preparation</td>
<td>Refer to Fig. A3.2</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>52</td>
<td>Surface Preparation</td>
<td>Refer to Fig. A3.3</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>53</td>
<td>Stripe Coating</td>
<td>Refer to Fig. A3.12 (Explanations)</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Film Thickness</td>
<td>Refer to Figs. A3.9 and A3.14 (Explanations)</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Final Inspection</td>
<td>Final confirmation of completion of painting</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>56</td>
<td>Temperature Humidity and Dew Point</td>
<td>Refer to Fig. A3.15 (Explanations)</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Gas Concentration Of solvent</td>
<td>Refer to Fig. A3.15 (Explanations)</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Ventilation</td>
<td>Refer to Fig. A3.15 (Explanations)</td>
<td></td>
<td>Δ</td>
<td>Δ</td>
<td></td>
</tr>
</tbody>
</table>

FIG. A3.8 Inspection Standards
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 4   | Tank anodes                                                         | (1) Anodes may be installed in ballast tanks which are often loaded with sea water. 
(2) Anodes are not to be installed when dissolution of zinc into the tank contents presents problems (as in the case of jet fuel, etc.). |
| 7   | Dry film thickness for Ballast Tanks, Fore/Aft Peak Tanks, Wet Spaces and Water Tanks shown. See note for all other spaces. | Measurements at 80% of total measuring points must verify a film thickness exceeding or equal to a specified value (e.g., 300 microns). For the remaining 20%, the measured film thickness must be equal to or over 80% (e.g., 240 micron) of the specified thickness. (Note: All other tank spaces the 90-10 rule shall apply, All other surfaces to SSPC-PA 2) |
| 10  | Tank painting process (Typical; guideline only, deviations are acceptable) | (1) For tank coating, block painting, painting in a dry dock, afloat painting, or any combination is considered. However this standard is based on afloat painting only. 
(2) For abrasive blasting and painting in tank, the following two systems may be considered:  

![Diagram of Tank Painting Process](image)  

FIG. A3.9 General (Explanations)
### FIG. A3.10 Preparation Standards for Steel (Explanations)

#### Table 1: Division - Welding

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Tolerance Limits</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13</th>
<th>Undercut</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hgt. of reinf. brth. of bead, flank of ang.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undercut (butt weld)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin plate and face plate between 0.6&lt;sup&gt;o&lt;/sup&gt;</td>
<td>Over 90 mm continuous d = 1.6mm</td>
<td>To be repaired by welding electrode or other, (carefully avoid short bead for higher tensile steels).</td>
<td></td>
</tr>
<tr>
<td>Undercut fil</td>
<td>d = 1.6mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg lgh.</td>
<td>d = 0.5mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compared with correct ones</td>
<td></td>
<td>If over tolerance, fill weld to correct.</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 2: Division - Material

<table>
<thead>
<tr>
<th>section</th>
<th>Sub-section</th>
<th>Item</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Surface damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface flaw</td>
<td>Pit</td>
<td>Grade of pitting</td>
<td></td>
</tr>
<tr>
<td>Grade A is considered slight and no repair is necessary. Grade B is medium and is to be repaired if necessary. Grade C requires some repair.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade of pitting</td>
<td>Width = D = 0.7t, Depth = t = 0.2t grinding followed by welding.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface flaw</td>
<td>Flaking</td>
<td>Grade of surface flaw</td>
<td></td>
</tr>
<tr>
<td>Grade A is considered slight and no repair is necessary. Grade B is medium and is to be repaired if necessary. Grade C needs some repair.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade of surface flaw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade of surface flaw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair method of surface flaw: depth of defect = d, plate thickness = t, d = 0.07 t removed by grinding. (but in no case d = 3 mm). 0.07 t = d = 0.2 t grinding followed by welding.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Item</td>
<td>Explanation</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Moisture</td>
<td>Rainwater inflow and moisture in the air may produce sweat on steel surface. After secondary surface preparation, moisture may cause turning or hinder adhesion. Appropriate measures must be taken to prevent rainwater from flowing in.</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Oil and grease contaminants</td>
<td>In general, remove with a rag and thinner/cleaner. For heavy adhesion of grease and oil, first dissolve with a brush soaked in thinner/cleaner, then wipe off with a clean rag. Detect oil visually with a black light or water spray bottle (water break test).</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Dust and non-visual contaminants</td>
<td>Check for dust with clear tape, clean cloth or pictorial standard in accordance with ISO 8502-3. Remove dust by compressed air or vacuum. Non-visual contaminants may be removed in accordance with SSPC-SP 12/NACE No. 5 as applicable to meet the ship’s specification and manufacturer’s recommendation. Check for soluble salts according to ISO 8502-6 when required by manufacturer or ship’s specification.</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Chalk or slate pencil marks</td>
<td>Remove with a rag or brush. When marks enter an anchor-pattern concavity and are difficult to remove, use a hard brush.</td>
<td></td>
</tr>
</tbody>
</table>

**FIG. A3.10 (continued)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Solvent Cleaning</td>
<td>Surface cleanliness is to be in accordance with SSPC-SP 1. Note: SSPC-SP 1 is required prior to all other surface preparation methods.</td>
</tr>
<tr>
<td>27</td>
<td>Mechanical Cleaning</td>
<td>SSPC-SP 3 is the minimum accepted method of repair for non-immersion service substrates. (SSPC-SP 2 may be substituted where SSPC-SP 3 is impractical). SSPC-SP 11 is the minimum accepted method for repair of immersion service substrates. To determine surface cleanliness, refer to the SSPC-VIS 3 photographic standard. To determine surface profile use ASTM D 4417 Method A or B.</td>
</tr>
<tr>
<td>28</td>
<td>Abrasive Blast Cleaning and Surface Profile</td>
<td>SSPC-SP 10 is the minimum accepted surface preparation for pre-construction primer and for immersion service substrates. SSPC-SP 7 may be used in place of SSPC-SP 3 when practical. For cleanliness refer to SSPC-VIS 1-89 photographic standard. To determine surface profile use ASTM D 4417 Method A or B.</td>
</tr>
<tr>
<td>29</td>
<td>Water Jetting</td>
<td>Where acceptable according to the ship’s specification and manufacturer’s recommendations, clean in conformance with SSPC-SP 12/NACE No. 5. Refer to SSPC-VIS 4(1)/NACE No. 7 photographic standard. To confirm pre-existing surface profile use ASTM D 4417.</td>
</tr>
<tr>
<td>30</td>
<td>Abrasives</td>
<td>Blast surface color tends to vary depending on the abrasive material used. As long as the same grade of cleanliness is used, a difference in color does not affect the film performance. Abrasives to be determined according to SSPC-AB 1. Recycled Abrasive Cleanliness to be determined according to SSPC-AB 2.</td>
</tr>
<tr>
<td>31</td>
<td>Repairs to shop primed surfaces</td>
<td>(1) In general shop primer in the cargo oil and slop retention tanks shall be removed in accordance with manufacturer’s recommendation to a visual acceptance. (2) All other spaces intact shop primer may remain and over coated in accordance with manufacturer’s recommendation. (3) In no way does the above supersede the ship’s specification.</td>
</tr>
</tbody>
</table>

**FIG. A3.11 Surface Preparation Standards (Explanations)**
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Stripe coating in tanks.</td>
<td>Where airless spraying is difficult and the film thickness can not be maintained, apply stripe coating with a brush before or after spraying. Stripe coating locations are as follows:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(a) Inside and edges of holes ...... ①</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Free edges ...................... ②</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) Welding beads .................. ③</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(d) Where painting is difficult ...... ④</td>
</tr>
</tbody>
</table>

FIG. A3.12 Coating Standards (Explanations)
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 34  | “Sagging” | The “sagging” of the film needs repair due to the following causes:  
(1) Spray dust, dust, etc. tend to collect.  
(2) Sag having a large film thickness. Solvent tends to collect on high film thicknesses.  
If coating is applied over the “sagging” area, solvent evaporation becomes more difficult  
leading to possible cracks in the film.  
“Sagging” to be repaired is as follows:  
(a) Sagging with the height of 2mm and more.  
(b) Wide “sagging”  
(c) “Sagging” in the bottom corners |

FIG. A3.13 Coating Repair Standards (Explanations)
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 36  | Foreign matter | When abrasives are used in surface preparations (blasting), abrasives remaining may adhere to the substrate and be trapped in the film during painting.  
Foreign material shall be removed by screen, sanding, etc. as directed by the paint manufacturer. |
| 37  | Craters, pinholes, and bubbles | (1) Pinholes tend to occur at the pit of manual welding bead.  
(2) Craters tend to occur when surface tension becomes uneven during the film drying process. A crater is a concave, and reduces film thickness.  
(3) Bubbles occur when paint mixed with air is applied in the airless painting.  
Repairs to coating to be in accordance with manufacturer recommendations. Generally, surface will be feathered by sanding or screening and coating applied to achieve desired DFT. |
| 38  | "Blushing" | The film will "blush", due to humidity absorbed by the hardening agent. When humidity rises or dew is produced before curing, this may occur. Blushing is confined to the film surface and does not affect film performance. However, excessive blushing must be repaired because it hinders adhesion of overcoating. |
| 39  | Mechanical damage | The surface of the film shall be lightly abraded with sandpaper, screen, or as recommended by coating manufacturer and coating applied to the desired DFT.  
Feather |

FIG. A3.13 (continued)
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Film thickness measurement in tanks.</td>
<td>(1) Measuring equipment to be adjusted once a day by using a reference plate with a thickness nearest to the film thickness to be measured. (2) The measured value of film thickness to be marked at a measuring point using a specified marking material.</td>
</tr>
<tr>
<td>41</td>
<td>For other areas see Note.</td>
<td></td>
</tr>
</tbody>
</table>

Film thickness measuring point (x mark)

(a) Bottom part

(b) Deck part

**NOTE:**

(For all other areas, measure every 93m² (1,000 ft²) in accordance with SSPC-PA 2)

FIG. A3.14 Film Thickness Measurement Standards (Explanations)
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 44  | Temperature (During painting and drying) | (1) Lowest temperature  
   (a) Temperature must be 3°C or more above the dew point. Theoretically the steel plate surface temperature is used. However the air temperature in tank is practically used herein.  
   (b) Curing of epoxy resin slows down when the temperature drops below 10°C and 5°C is the lowest limit. It is preferable to keep the temperature above 10°C and in conformance with the paint manufacturer’s recommendation.  
   (2) Highest temperature  
   The maximum temperature is affected by the type of paint used and the painting process. Consult the paint manufacturer for maximum allowable temperature for application and cure. |
| 45  | Humidity (During painting, and initial drying) | Relative humidity is to be below 85%. This value applies when the painted surface temperature is equal to or above the atmospheric temperature. |
| 46  | Ventilation | (1) The amount of ventilation required during painting and drying is greater than that required for blasting due to the following reasons:  
   (a) The film begins hardening with evaporation of solvents in the film.  
   (b) Solvent evaporation is greatly influenced by ventilation and temperature.  
   (c) Retained solvents affect film performance.  
   (2) Air change rate  
   This standard is determined for correct film performance and this varies depending on tank capacity. These standards are different from OSHA 29 CFR 1915 35 and OSHA 29 CFR 1926.57. Consult “Industrial Ventilation, 20th Edition” and OSHA Technical Manual Section III: Chapter 3 for guidance.  
   (3) Air change rate for high humidity (85% RH or above). With high humidity, dew must be prevented after painting, from blasting stages up to the film hardening stages. Otherwise, the following may occur:  
   (a) Turning of blasted surfaces  
   (b) Film defects (Blushing, poor adhesion)  
   As described above in (1) insufficient ventilation also deteriorates film performance. Consequently it is preferable to ventilate at least three times per hour even with high humidity for two days (this varies according to the type of paint) immediately after painting. |

FIG. A3.15 Environmental Painting Standards (Explanations)
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 46 47 | The safety and Health Standards for Painting | (1) The safety and Health Standards for Painting  
(a) When gas concentration reaches 10% of the lower explosion limit (LEL), stop operations and evacuate workers.  
(b) When gas concentration exceeds 10% of the lower explosion limit (LEL), take appropriate measures such as adding fans and reducing the number of paint sprayers. Refer to OSHA 29 CFR 1915.35 and 29 CFR 1926.57 Consult "Industrial Ventilation, 20th Edition" 1 OSHA Technical Manual Section III: Chapter 3 for guidance. |
| 45 46 47 | Instruments for measuring environmental conditions | (1) For humidity and dew point:  
Sling psychrometer and psychrometric tables or battery operated psychrometer according to ASTM E 337 Standard.  
(2) Surface temperature  
Magnetic contact surface thermometer.  
(3) Anemometer  
Used to measure the ventilation volume and rate. |
| 48 49 | Erection of scaffoldings | (1) Scaffolding pieces  
Scaffolding pieces not to be removed are recommended to be of stainless steel.  
(2) The distance between painted surfaces and scaffolding is to be between 150 and 300 mm (to prevent unpainted portions).  
(3) Scaffold planks of expanded metal or similar open design to assist in abrasive removal and ventilation.  
(4) Height of scaffolding; 1,700 to 1,900 mm (to ensure easy and satisfactory work). |
| 50 | Illumination | Explosion-proof lighting is to be used during painting and drying. |

FIG. A3.15 (continued)
Standard Guide for
Database Structure of Electronic Data Interchange Between
Ship Owner and Shipyard for Contract Administration\(^1\)

This standard is issued under the fixed designation F 2017; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This standard provides the database structure of electronic data interchange (EDI) information between ship owner and a shipyard for contract administration. Ship owners (hereinafter referred to as owners) and shipyards may each have unique software programs to manage their respective portions of a ship repair period. There is information that must be exchanged between the parties during the contract period. This standard has been developed to establish common field lengths, names, and types such that the exchanged information can be used directly by the respective software programs without scanning, typing, or redundant keying of information.

2. Terminology
2.1 Definitions of Terms Specific to This Standard:
2.1.1 BLOB—short for binary large object, a collection of binary data stored as a single entity in a database management systems (DBMS). BLOBs are used primarily to hold multimedia objects such as images, videos, and sound, though they can also be used to store programs or even fragments of code. Not all DBMSs support BLOBs.

2.1.2 CHAR(XX)—character data, alphanumeric where XX represents the maximum number of characters permitted and SQL fills the remaining spaces with blanks if fewer than the maximum are entered.

2.1.3 Condition Found Report (CFR)—a report generated by the shipyard to inform the owner of conditions found, deficiencies with the specification, or any other pertinent information regarding a particular work item.

2.1.4 Condition Found Report Response—the owner’s response back to the shipyard’s Condition Found Report. It may be a simple acknowledgement of receipt or a lengthy response and reference to a Request for Proposal.

2.1.5 DATE—stores the year, month, and day values of a date. The length of a DATE is ten positions, as in 01/31/2000 (for 31 Jan 2000).

2.1.6 INTEGER—a number that has no fractional part and its precision (maximum number of digits) depends on the specific SQL implementation.

2.1.7 owner—in this case, the recognized authority for contracting ship repair work.

2.1.8 Request for Proposal—an owner-generated document asking the shipyard to add, modify, or delete work to the existing package. It may or may not be related to a shipyard initiated CFR.

2.1.9 shipyard—in this case, the principal party to a contract with a ship owner.

2.1.10 SQL compliant—an industry standard data sublanguage, specifically designed to create, manipulate, and control relational databases. SQL-92 is the latest version of the standard.

2.1.11 tests and trial agenda—the agenda provided by the shipyard, which details the planning schedule for all testing events to be conducted during a dock or sea trial.

3. Significance and Use
3.1 Intended Use—Compliance with this practice will allow the sharing of electronic data between contracting parties that is normally done by hard copy. This can only be used when both parties use a database-derived software package to manage their contracts. Specifically, it will:

3.1.1 Eliminate the duplication of manual entry of data into each party’s contract administration software package and
3.1.2 Allow for wide access of the data to all authorized parties.

4. Database Structure
4.1 A shipyard contract management database, or an owner contract management database, may contain hundreds of tables and fields and thousands of records. Much of the data is business-sensitive and must remain under the control of the party. However, there is data that is shared and common to both parties in a ship repair contract.

4.2 Condition Found Report—A Condition Found Report, generated by the shipyard and forwarded to the owner, will be structured as follows:
4.3 **Condition Found Report Response**—A Condition Found Report Response, generated by the owner and forwarded to the shipyard, will be structured as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Required Field</th>
<th>Type</th>
<th>Size</th>
<th>Data Element</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition Found Report ID</td>
<td>Y</td>
<td>CHAR</td>
<td>10</td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Contract number</td>
<td>Y</td>
<td>CHAR</td>
<td>16</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Work item number</td>
<td>Y</td>
<td>CHAR</td>
<td>7</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Equipment ID number</td>
<td>N</td>
<td>Integer</td>
<td>12</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Ship name</td>
<td>N</td>
<td>CHAR</td>
<td>30</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Date Condition Found Report</td>
<td>Y</td>
<td>DATE</td>
<td>10</td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Generated</td>
<td></td>
<td>MM/DD/YYYY</td>
<td></td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Shipyard POC</td>
<td>Y</td>
<td>CHAR</td>
<td>30</td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>Y</td>
<td>memo</td>
<td>BLOB</td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Recommendation</td>
<td>N</td>
<td>Memo</td>
<td>BLOB</td>
<td>shipyard</td>
<td></td>
</tr>
</tbody>
</table>

4.4 **Request for Proposal**—A Request for Proposal, generated by the owner and forwarded to the shipyard, will be structured as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Required Field</th>
<th>Type</th>
<th>Size</th>
<th>Data Element</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFP ID</td>
<td>Y</td>
<td>INTEGER</td>
<td>4</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Condition Found Report ID</td>
<td>Y</td>
<td>CHAR</td>
<td>10</td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Owner contract number</td>
<td>Y</td>
<td>CHAR</td>
<td>16</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Shipyard contract number</td>
<td>Y</td>
<td>CHAR</td>
<td>16</td>
<td>shipyard</td>
<td></td>
</tr>
<tr>
<td>Ship name</td>
<td>N</td>
<td>CHAR</td>
<td>30</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>RFP date</td>
<td>Y</td>
<td>DATE</td>
<td>10</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>(MM/DD/YYYY)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner POC</td>
<td>Y</td>
<td>CHAR</td>
<td>30</td>
<td>owner</td>
<td></td>
</tr>
<tr>
<td>Statement of work</td>
<td>Y</td>
<td>memo</td>
<td>BLOB</td>
<td>shipyard</td>
<td></td>
</tr>
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4.5 **Proposal**—A Proposal, in response to an RFP and generated by the shipyard and forwarded to the owner, will be structured as follows:

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4.6 **Test and Trial Agenda**—A TTA, generated by the shipyard and forwarded to the owner, will be structured as follows:

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^A The event table will include the test name, equipment name, start time, and required attendees (witnesses).

5. **Keywords**

5.1 contract administration; database; electronic; owner; shipyard
Standard Guide for the Basic Elements of a Shipboard Occupational Health and Safety Program

1. Scope

1.1 This guide covers the basic elements of a Shipboard Occupational Health and Safety Program (SOHSP). These elements are applicable to all vessel types including but not limited to tank vessels, dry bulk carriers, passenger vessels, roll-on roll-off vessels, ore bulk oilers, offshore supply vessels, tugboats, towboats, and barges. The elements described are fundamental pieces of a systematic occupational safety and health program and may be used by company line managers, health and safety personnel or consultants who are implementing, improving, or auditing the effectiveness of a shipboard health and safety program.

1.2 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ANSI Standards:
- ANSI Z41-1991 Personal Protection – Protective Footwear
- ANSI Z87.1-1989 Practice for Occupational and Educational Eye and Face Protection
- ANSI Z88.2-1992 Respiratory Protection
- ANSI Z89.1-1986 Protective Headwear for Industrial Workers
- ANSI Z244.1-1982 (R1993) Safety Requirements for the Lock Out/Tag Out of Energy Sources
- ANSI/ASA S3.44-1996 Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment
- ANSI/AWS Z49.1-1994 Safety in Welding, Cutting and Allied Processes

2.2 Other Documents:
- NFPA 306-1997 Control of Gas Hazards on Vessels
- NFPA 1991-2000: Vapor Protective Suits for Hazardous Chemical Emergencies
- IMO A.468(XII) Code on Noise Levels Onboard Ships
- IMO A.849 (20) Code for Investigation of Marine Casualties and Incidents
- IMO A.864 (20) Recommendations for Entering Enclosed Spaces Aboard Ships
- 46 CFR 16.210 Pre-employment Testing Requirements
- U.S. Coast Guard Navigation and Vessel Inspection Circular 2–98 Physical Evaluation Guidelines for Merchant Mariner’s Documents and Licenses

3. Significance and Use

3.1 This guide does not set specific performance or technical criteria, but recommends that companies set policies and objectives and develop procedures for managing their health and safety program. Companies should consider their unique organization, culture, and hazards on their vessels and the possible effects of their operations. The elements are intentionally flexible and may be tailored to address any size of operation or any vessel type. Note that although the standard is aimed at the shipboard occupational health and safety program, some of the elements address activities and commitments that must be completed or made by shore side personnel (for example, executive management commitment and provision of adequate resources). Key to the effectiveness of the program is the implementation of each element within an interconnected system.

4. Basic Elements

4.1 Executive Management Commitment and Leadership—Executive management commitment and leadership is a precondition for an effective SOHSP. Executive management
commitment and leadership includes, but is not limited to integrating health and safety into the management structure and fabric of the company, developing a health and safety policy, developing health and safety objectives, providing resources to achieve the objectives, defining stewardship responsibilities and providing authority to carry out those responsibilities, and establishing accountability for safety and health as a part of job performance reviews. Further guidance is provided in Annex A1.

4.2 Employee Participation—Employees from all levels including crewmembers, officers, masters, persons in charge, and shoreside personnel should be directly involved with the SOHSP. Shipboard and shoreside employees should be involved in developing, implementing, evaluating, and modifying the SOHSP. Employees should also participate in setting health and safety objectives and performance criteria. This involvement might be through employee membership on safety committees that provide input to management for the development of safety and health policy, debate and set health and safety goals, measure and evaluate performance, and recommend modifications to the program based on their evaluation. Shoreside and shipboard employees should work together to achieve safety and health goals. For example, shoreside personnel should participate on vessel safety committees since their decisions affect vessel operations and ultimately the health and safety of vessel personnel. In large companies, individual vessel safety committees might submit recommendations to an overarching safety committee that evaluates the recommendations and sets policy to apply appropriate recommendations to the entire fleet. Further guidance is provided in Annex A2.

4.3 Hazard Anticipation, Identification, Evaluation and Control—The core function of any health and safety program is prevention. Health and safety hazards including fire, reactivity, and chemical and physical hazards, need to be anticipated and prevented from occurring. Hazards and unsafe operating procedures need to be identified and addressed so they will not endanger employees or the public and will not damage the vessel, cargo, or third party property. Potential hazards should be systematically anticipated, identified, evaluated, and controlled. Tools such as job hazard analysis, industrial hygiene exposure assessments, and risk assessment/management methodologies enable the evaluation and control of hazards. Further guidance is provided in Annex A3.

4.4 Training—Employees should receive training appropriate for their duties and responsibilities so that they may work safely and not endanger their shipmates or the public. In addition, employees who have specific health and safety responsibilities (generally supervisors with responsibility for the safety of others, but also nonsupervisors who are assigned to safety committees or as crew member representatives) should receive training to enable them to carry out their health and safety program responsibilities. Further guidance is provided in Annex A4.

4.5 Record Keeping—Company records sufficient to demonstrate the effectiveness of the health and safety program should be maintained. Data that enables trend or pattern analysis for root causes is particularly desirable. For example, results of audits that evaluate effectiveness of the safety and health management system should be maintained. Records that indicate industrial hygiene exposure assessments have been conducted and appropriate controls have been implemented should be maintained. Current job safety analyses and corresponding standard operating procedures with safe work practices should be documented. Injury and illness data should be maintained to enable the identification of trends and patterns that associate the injury or illness with a common cause, which can be addressed. Training topics, lesson outlines, and attendees should be documented. Where appropriate, such records should permit evaluation of the program on individual vessels as well as across an entire fleet. Further guidance is provided in Annex A5.

4.6 Contract or Third Party Personnel—When contract or third party personnel are on board to perform work, vessel personnel should provide information regarding potential hazards on the vessel that may affect the contract or third party personnel. Potential hazards related to the work conducted by contract or third party personnel should be provided to the vessel owner/operator and/or the master/person in charge. Each employer should provide appropriate information regarding vessel and work hazards to their own employees. For example, exchange of information on chemical hazards might be accomplished by exchanging appropriate material safety data sheets (MSDS), then each employer can inform their own employees of the hazards identified in the MSDS. Further guidance is provided in Annex A6.

4.7 Fatality, Injury, Illness, and Incident Investigation—Personnel injuries, occupational illnesses, and “near miss” incidents should be promptly investigated. The current incident and other similar occurrences should be analyzed to identify the primary (root) cause and any contributing factors. The investigation report, setting forth primary cause, contributing factors, and corrective measures should be presented to management. Followup action that specifically addresses the report’s recommendations for corrective action should be undertaken and documented. Further guidance is provided in Annex A7.

4.8 Systematic Program Evaluation and Continuous Improvement—Maintaining an effective health and safety program is an ongoing process. The SOHSP should have systems for detecting, reporting, and correcting nonconformities to the program. Some type of “formalized” evaluation should also be conducted on a periodic basis consistent with other aspects of the vessel’s management plan. The evaluation should determine whether the SOHSP is appropriate for the vessel and its operations, that actual practices are consistent with the programs and procedures in the SOHSP, and that the SOHSP is effective. Comparison of data and records (refer to Annex A5, Record Keeping) to performance objectives and criteria (refer to Annex A1, Section A1.3, health and safety objectives) can provide important indicators of the effectiveness of the SOHSP. Further guidance is provided in Annex A8.

5. Keywords

5.1 health; safety
A1. MANAGEMENT COMMITMENT AND LEADERSHIP

A1.1 Health and safety programs are most effective when they are integrated into the management structure of a company, rather than treated as an “add on” program. Examples of integrated health and safety efforts include:

A1.1.1 Developing Standard Operating Procedures (SOPs), written to the education level of the person who must follow the SOP, that integrate safe work practices and basic operational functions,

A1.1.2 Making design review by qualified health and safety personnel an element of the acquisition procedures, and

A1.1.3 Making consultation with qualified health and safety personnel a part of the process when making changes to operations.

A1.2 Executive management sets the tone for the entire SOHSP through their policy regarding health and safety. Examples of values that can be stated and commitments that can be made in company policy include:

A1.2.1 A statement that the company will make every effort to provide a safe and healthy workplace and that working safely is a condition of employment,

A1.2.2 Statements that convey how important each crew member is to the vessel as a fellow worker and as a company resource:

A1.2.2.1 “The basic safety policy of this company is that no task is so important that an employee must violate a safety rule or put himself or herself at risk of injury or illness in order to get it done.”,

A1.2.3 A written commitment to provide resources necessary to implement the health and safety program could also be included in the policy statement, and

A1.2.4 Management can demonstrate commitment to the safety and health policies through word and action. For example, managers visiting vessels should follow safety rules and standard operating procedures, including use of hearing protection, safety glasses, safety shoes, protective clothing, and so forth.

A1.3 Setting and attaining health and safety objectives demonstrates a company’s commitment to improvement of health and safety performance. Objectives provide a target against which those who are responsible for health and safety may measure their progress. Quantifiable objectives are desirable since often, “What gets measured gets done.” (Refer to Annex A8, Systematic Program Evaluation, for examples of performance measures and an overall program audit.) Health and safety objectives may include:

A1.3.1 Eliminate lost time incidents,

A1.3.2 Report “near miss” incidents or problems, evaluate, and if appropriate, implement changes to prevent a more serious incident or accident in the future,

A1.3.3 Develop and implement a program of evaluations through drills and other means (for example, simulators) to ensure that personnel are competent to carry out their duties,


A1.3.5 Complete periodic comprehensive (or area-specific) hazard review.

A1.3.6 Reduce exposure levels to airborne vapors to acceptable levels through appropriate controls,

A1.3.7 Complete annual respiratory fit testing on schedule,

A1.3.8 Develop and implement acute toxic exposure procedures addressing first aid procedures, obtaining additional emergency medical assistance, and appropriate medical surveillance tests (for example, S-phenylmercapturic acid in urine following a potential benzene overexposure), and

A1.3.9 Develop and implement an occupational health medical surveillance plan.

Note A1.1—The intent of this medical surveillance plan is to ensure employees are not overexposed to hazards on the job including chemicals, radiation, noise, and so forth. This section is not intended to address requirements of the Americans with Disabilities Act or issues covered by physical standards related to watch keeping published elsewhere.

A1.4 Company management holds the authority to dedicate necessary resources to achieve health and safety objectives. Necessary resources may include:

A1.4.1 Access to health and safety information,

A1.4.2 Training, including classroom and on-the-job training, that cover topics identified by the company’s risk assessment process as well as those required by international or national standards. These topics would include but not be limited to existing chemical and mechanical hazards,

A1.4.3 Qualified health and safety professionals, either on the company staff or hired as consultants,

A1.4.4 Capital investments in engineering controls, and

A1.4.5 Personal protective equipment.

A1.5 Defining stewardship responsibilities and providing authority to carry out those responsibilities is an essential component of management commitment. For example:

A1.5.1 Company Management Should:
A1.5.1.1 Designate a shoreside person who has access to the executive management of the company and is responsible to ensure essential health and safety issues are clearly communicated to executive management of the company and decisions regarding those issues are clearly communicated back to the vessel.
A1.5.1.2 Ensure adequate resources of time, funds for health and safety equipment, training and expertise are available to effectively implement the program throughout the company.
A1.5.1.3 Ensure that a safety committee or other mechanism to involve crewmembers in health and safety issues is created on each vessel adequately.
A1.5.1.4 Ensure that the elements of the shipboard health and safety program are integrated and systematically implemented throughout the company and on each vessel.
A1.5.1.5 Ensure that objectives are developed and performance measures are reported from each vessel.
A1.5.1.6 Ensure that all appropriate programs are developed and implemented including, but not limited to respiratory protection, hearing protection, confined space entry, and lock out-tag out.
A1.5.1.7 Set a good example for employees by following established safety rules on vessels and by staying current on training commensurate with duties.
A1.5.1.8 Report unsafe practices or conditions observed while on a vessel to the supervisor of the area.
A1.5.2 Master/Person-In-Charge/Operator Should:
A1.5.2.1 Ensure each crewmember receives an initial vessel orientation, covering company safety policy, emergency procedures, access and egress, fire fighting, job hazards, and information on hazardous materials before beginning work. Document the completion of this orientation.
A1.5.2.2 Ensure each crewmember is competent to perform a task or job by requiring a prejob explanation and/or walk through of all procedures including safe work practices before starting work on that project or equipment. Require prejob refresher training if the employee cannot demonstrate this competence.
A1.5.2.3 Ensure each crewmember has been issued and received training on the use of required personal protective equipment (PPE) before starting work on a project requiring PPE.
A1.5.2.4 Complete periodic walk-around health and safety checks of the vessel (accompanied by appropriate personnel including those who have responsibilities or work in certain areas, for example, chief engineer and an oiler in engine spaces and first mate and able-bodied seaman on deck).
A1.5.2.5 Periodically observe work performance of employees for compliance with safety rules contained or documented in the SOHSP.
A1.5.2.6 Set a good example for subordinates by following established safety rules and attending training as appropriate.
A1.5.2.7 Complete a preliminary investigation of all accidents and report findings to company management.
A1.5.2.8 Provide information to company management suggesting changes to company-wide standard operating procedures or equipment that will improve employee safety.
A1.5.3 Officers/Other Management Personnel Should:
A1.5.3.1 Act as the master’s or person-in-charge’s representative and implement examples listed for the master in areas over which they exercise supervision (for example, first mate responsible for “deck” personnel and Chief Engineer responsible for “engineers”).
A1.5.4 Management should establish accountability for health and safety as part of job performance reviews. Performance reporting regarding health is as important and should be as routine within the company as reports regarding timeliness of delivery, cargo loss or contamination, or citations regarding violations of regulations.

A2. EMPLOYEE PARTICIPATION

A2.1 Full participation in developing, implementing, evaluating, and continually improving the SOHSP helps those on board the vessel see the SOHSP as something that is the result of a value they share with vessel owners/operators. Personnel directly involved with the work are often the best source of information on health or safety hazards and often can suggest effective methods for abating those hazards. Shoreside personnel need to be directly and heavily involved with the SOHSP because they are integral in setting the rules and schedules for vessel operation. Shoreside personnel also represent the vessel to management and are the link to the resources and authority necessary for the success of the SOHSP. Specific ways that crewmembers, officers, and shoreside personnel can contribute to the SOHSP include:
A2.1.1 Participating in periodic vessel inspections,
A2.1.2 Evaluating safety and health program materials,
A2.1.3 Developing standard operating procedures that incorporate safe working practices,
A2.1.4 Conducting job safety/hazard analyses (JSAs/JHAs),
A2.1.5 Reviewing and analyzing injury and illness data,
A2.1.6 Participating in risk assessment and risk management activities,
A2.1.7 Participating in accident/incident/problem investigations,
A2.1.8 Developing solutions to health and safety complaints and disputes,
A2.1.9 Evaluating safety and health training activities, and
A2.1.10 Evaluating the safety and health management system.
A2.1.11 Line or operations personnel including crewmembers, officers, and shoreside personnel outside the health and safety staff may need training in health and safety techniques such as job safety/hazard analysis, reviewing injury and illness data for trends, risk assessment, and investigations. This initial training investment enables those who do the work to meaningfully participate in identifying and solving health and safety
problems. Those crewmembers, officers, and shoreside personnel who receive additional training in health and safety and actively participate in the development of the vessel or company SOHSP, or both, also become health and safety “champions” among their peers. Additional information on training is provided in Annex A4.

A2.2 Since health and safety objectives and performance may directly affect crewmembers’ and officers’ current and/or future health and safety, they should be involved in setting those objectives and performance criteria. This participation may be accomplished through health and safety committee involvement, labor negotiations, or other mechanism suitable to the specific company. Refer to Annex A1, Section A1.3 for examples of health and safety objectives and performance criteria.

A2.3 Employees should:

A2.3.1 Fully understand (including underlying principles) and follow established standard operating procedures and safety rules.
A2.3.2 Report unsafe conditions or actions to supervisor as soon as they become aware of them.
A2.3.3 Report all injuries to supervisor promptly.
A2.3.4 Report all accidents, near misses, or problems to supervisor promptly.
A2.3.5 Use personal protective equipment (PPE) in good working condition where it is required.
A2.3.6 Do not remove or defeat any safety device or safeguard.
A2.3.7 Encourage shipmates by words and behavior to follow standard operating procedures and use safe work practices on the job.
A2.3.8 Make suggestions to supervisor or safety committee representative about changes to operating procedures, work practices, or equipment that will improve safety.

A3. HAZARD ANTICIPATION, IDENTIFICATION, EVALUATION AND CONTROL

A3.1 Potential hazards on the vessel and created by the vessel should be systematically anticipated, identified, evaluated, and controlled. Hazards that should be discovered, evaluated, and controlled by the SOHSP include hazards addressed by international conventions and national regulations and other hazards that are causing or likely to cause illness, death, or serious physical harm to workers or the public. Types of hazards to consider may include:

A3.1.1 Hazardous atmospheres caused by oxygen deficiency, flammable or toxic gases or vapors, and biological agents,
A3.1.2 Chemical hazards and the proper handling of vessel generated hazardous wastes,
A3.1.3 Physical hazards including noise, vibration, radiation, electricity, uncontrolled mechanical energy, and shifting cargoes that may engulf a crewmember,
A3.1.4 Ergonomic factors including fatigue, workstation design, and poor team practices,
A3.1.5 Collisions, groundings, or rammings and their resultant impacts, and
A3.1.6 Drowning.

A3.2 Methods of anticipation include:

A3.2.1 Systematic requirements for vessel and equipment design and modification review by qualified health and safety personnel,
A3.2.2 Periodic management review of the vessel and its operation, its equipment, and its fitness for purpose,
A3.2.3 A procurement system that automatically requires consideration of health and safety aspects of items ordered,
A3.2.4 Consideration of fitness for current conditions, and
A3.2.5 Systematic review of vessel and shoreside team practices.

A3.3 Methods of identifying hazards include:

A3.3.1 Vessel inspections,
A3.3.2 Industrial hygiene exposure assessments of chemical and biological hazards including inhalation and dermal exposure routes and physical hazards such as vibration and ergonomic hazards,
A3.3.3 Job safety analyses including risk assessment, both statistical and expert opinion based,
A3.3.4 Employee hazardous condition notification system including easy-to-understand labeling system for all possible mechanical and chemical hazards,
A3.3.5 Review of available safety and health data to identify trends,
A3.3.6 Readers interested in physical standards may refer to U.S. Coast Guard Navigation and Vessel Inspection Circular 2-98, Physical Evaluation Guidelines for Merchant Mariner’s Documents and Licenses, and

A3.4 Methods of hazard evaluation include:

A3.4.1 Comparison of industrial hygiene exposure levels to standards identified in the SOHSP (for example, standards required by regulation or prudent levels adopted by the company in the absence of regulatory requirements),
A3.4.2 Risk analysis tools, including:
A3.4.2.1 Hazard effects and control analysis,
A3.4.2.2 Hazard control analysis,
A3.4.2.3 Fault tree analysis of possibilities based on expert opinion,
A3.4.2.4 Management oversight and risk analysis, and
A3.4.2.5 Task hazard analysis.
A3.4.5 Methods of hazard control are hierarchical. In order of preference, they include:

A3.5.1 Inherent safe design and verification of design output to design requirements,
A3.5.2 Material substitution such as:
A3.5.2.1 Nonhazardous insulation for asbestos lagging,
A3.5.2.2 Citrus-based cleaning agents for solvent-based cleaning agents, and
A3.5.2.3 Nontoxic paint for toxic paint.
A3.5.3 Engineering controls such as:
A3.5.3.1 Closed gauging,
A3.5.3.2 Vapor recovery systems, and
A3.5.3.3 Climate-controlled spaces such as control booths in engine rooms.
A3.5.4 Administrative controls such as:
A3.5.4.1 Systematic review for fitness of vessel for operations,
A3.5.4.2 Standard operating procedures that incorporate safe work practices. Some activities that might require standard operating procedures with integrated safe work practices include:
A3.5.4.3 Machinery startup and shutdown operations,
A3.5.4.4 Emergency response to machinery failures,
A3.5.4.5 Getting underway and entering port operations,
A3.5.4.6 Cargo loading and unloading operations,
A3.5.4.7 Response to unplanned or emergency situations during cargo operations,
A3.5.4.8 Man overboard procedures,
A3.5.4.9 Lifeboat-launching procedures,
A3.5.4.10 Watchkeeping procedures,
A3.5.4.11 Teamworking procedures such as bridge resource management taught in simulators with practice by actual team members,
A3.5.4.12 Prejob planning and briefings,
A3.5.4.13 Job hazard/safety analyses (JHAs/JSAs),
A3.5.4.14 Emergency procedures,
A3.5.4.15 Systematic inspection of incoming equipment and equipment in use to ensure conformation to specifications identified in the SOHSP (for example, personal protective equipment),
A3.5.4.16 An easy-to-understand labeling system for all possible mechanical and chemical hazards, and
A3.5.4.17 Occupational medical surveillance programs tailored to vessel and cargo hazards.
A3.5.5 Specific programs that need special attention within the overall SOHSP:
A3.5.5.1 Respiratory protection program,
A3.5.5.2 Hearing loss prevention program,
A3.5.5.3 Safe lifting procedures,
A3.5.5.4 Permit-to-work programs for operations such as lock out and tag out, tank or hold cleaning operations, confined space entry, hot work operations, including a gas-freeing program, working aloft, and
A3.5.5.5 Health and safety equipment control, calibration, and maintenance procedures.
A3.5.6 Security procedures to control entry and exit of personnel to and from the vessel
A3.5.7 Basic safety rules such as:
Do not do things which are unsafe to get the job done. If a necessary activity is unsafe, report it to the supervisor so it can be evaluated and alternate methods developed.
Mechanical guards must be kept in place at all times when machinery is being operated. Do not remove or disable any safety device!
No person may operate a piece of equipment unless they have been trained and are authorized. Notify supervisor that training is needed if asked to perform a function not learned in meeting the requirements for your license.
Use personal protective equipment whenever it is required.
Obey all safety warning signs.
Smoking is only permitted in designated locations and may be entirely prohibited at certain times, such as during cargo transfer operations.
Good housekeeping is an important part of accident prevention. Replace all tools and supplies after use. Do not allow rubbish or debris to accumulate where they will become a hazard.
A3.5.8 Employee assistance and wellness programs,
A3.5.9 Preemployment chemical tests for dangerous drugs,
A3.5.10 Incentive programs such as safety awards, bonuses, and vessel competitions, and
A3.5.11 Disciplinary policy that provides for progressive consequences depending on the severity or repetition of the violation of a safety rule, or both.
A3.5.12 Personal protective equipment such as:
A3.5.12.1 Safety glasses, goggles, hearing protection, safety shoes, protective clothing, chemical protective booties, respiratory protection, and
A3.5.12.2 Impervious gloves for food handlers as appropriate.
A3.5.13 Preventive maintenance of the vessel and equipment and basic housekeeping programs.

A4. TRAINING

A4.1 Training to enable all employees to recognize hazards and to take appropriate precautions should include:
A4.1.1 General orientation to the company,
A4.1.2 Overview of the company’s health and safety program,
A4.1.3 Vessel orientation including access and egress,
A4.1.4 Emergency procedures in case of fire, confined space entry incident, release of hazardous chemicals or cargo, and overexposure,
A4.1.5 The nature of potential hazards to which employees may be exposed during routine tasks and how to recognize symptoms of exposure,
A4.1.6 Use of protective measures, such as standard operating procedures that incorporate safe work practices, and protective equipment and clothing (refer to Annex A3, Section A3.5, Hazard Control).

A4.1.7 Specific programs including respiratory protection, confined space entry, hearing loss prevention, lockout-tagout, fall protection, safe lifting, health and safety equipment control, calibration and maintenance, and

A4.1.8 Recognition and control of fatigue.

A4.2 Additional training for those with specific health or safety responsibilities may include:

A4.2.1 Risk assessment and risk management including:

A4.2.1.1 Health and safety data trend analysis,
A4.2.1.2 Job safety analysis, and
A4.2.1.3 Shipboard watch implications.

A4.2.2 Fatality, injury, illness, “near miss” incident, and problem investigation and root cause analysis.

A4.3 Effective worker protection programs do not stop at initial training. Effective programs evaluate the success of the training provided and offer refresher training on both a routine and as-needed basis.

A4.4 Elaborate training programs solely related to safety and health are not always needed. Integrating consideration of safety and health protection into all organizational activities is the key to effectiveness. Safety and health information should be integrated into other training about performance requirements and job practices.

A5. RECORD KEEPING

A5.1 Records are needed to document hazard control efforts such as job hazard analyses, industrial hygiene sampling, and training. Data collection systems that enable trend analysis help in identifying injuries and illnesses with common causes. A review of shipboard personnel injury and illness experience over a period of time may reveal patterns of injury and illness with common causes, which can be addressed. Similarly, a review of accidents, “near miss” incidents, or problems over time can reveal patterns of dangerous practice, which need correction to assure safety. The correlation of changes in injury, illness, and “near miss” incident or problem experience with changes in the safety and health program, operations, work processes, and personnel may help to identify potential causes and likelihood of personnel accidents, injuries, and illnesses, and danger or risk to the public. Audits that evaluate the effectiveness of the health and safety program can be used to identify weak points in the system.

A5.2 Examples of records that should be maintained include:

A5.2.1 Death, injury, illness, accident, “near miss” incident, and problem data including:

A5.2.1.1 Investigation reports and root cause analysis (see also Annex A7, Fatality, Injury, Illness, and Incident Investigation), and
A5.2.1.2 Injury, illness, near miss, and problem rates.

A5.2.2 Hazardous condition notifications and abatement actions,
A5.2.3 Crew member safety suggestions,
A5.2.4 Industrial hygiene monitoring results for both personal and area samples,
A5.2.5 Job safety analyses,
A5.2.6 Safety committee reports,
A5.2.7 Safety inspection reports or log entries,
A5.2.8 Medical surveillance data (aimed at identifying exposures so that proper interventions, including improvement of hazard controls, may be initiated),
A5.2.9 Training (refer to Annex A4 for a discussion of recommended training):
A5.2.9.1 Record training outline, date, and attendance,
A5.2.9.2 Record completion of courses such as fire fighting and confined space entry schools, and
A5.2.10 Safety and health management system audits (refer to Annex A8 for an example).

A5.3 The extent of recordkeeping necessary to document the effectiveness of the program will vary depending on the size of the company, level and nature of exposure to hazards on the vessel, and other factors. The records should be maintained as long as necessary in light of their intended use.

A5.4 Records of individual ships should also be shared with other ships and analyzed as a larger base of data to gain information on frequency of problems to identify trends better.

A6. CONTRACT OR THIRD PARTY PERSONNEL

A6.1 The vessel owner/operator or the master/person-in-charge, or both, should provide information on applicable elements of the company’s health and safety program, vessel hazards, safety rules, standard operating procedures, and emergency procedures with contract or third party personnel who may be exposed to vessel or cargo hazards.

A6.2 The contractor or third party should inform his/her employees of the applicable elements of the vessel’s health and safety program and of any known vessel or cargo hazards to
which his/her employees may be exposed. The contract or third party person-in-charge should also direct his/her employees to follow the health and safety rules of the vessel to the extent that they meet or exceed the contractor’s or third party’s own requirements.

A6.3 The contract or third party person-in-charge should inform the vessel’s master or person-in-charge of any health and safety hazards presented by their work and how they will address those hazards. The contract or third party person-in-charge should also inform the vessel personnel of any other health and safety hazards in the course of their work on the vessel.

A6.4 During the initial exchange of information regarding vessel hazards and hazards presented by the work intended, the actions of the contractor or third party toward the health and safety of the vessel crew and their own employees should be clearly identified. Likewise, the actions of the vessel personnel toward the health and safety of the contractor or third party should be clearly identified. Emergency procedures should be clearly agreed upon in advance.

A7. FATALITY, INJURY, ILLNESS AND INCIDENT INVESTIGATION

A7.1 The objective of an investigation is to prevent related incidents from recurring. An investigation should identify the circumstances of the injury, illness, or incident and reveal the proximate causes, contributing factors, and root causes by gathering and analyzing information and drawing conclusions. Identification and correction of causes may prevent similar incidents from recurring. Furthermore, identifying and correcting a true root cause may prevent other, apparently unrelated incidents, giving even more return on the effort expended to identify root causes. For example, if a problem with the company’s training system was identified as the root cause for a confined space incident, then correcting the entire training system may prevent an injury that would have been caused by an untrained person improperly operating a piece of machinery.

A7.2 Start the investigation as soon as possible after the incident occurs. Interview workers involved in the incident and all witnesses. Discover situations leading up to the incident including several days before. These situations may include contributing factors. (Human factors including fatigue often are found as root or contributing factors and may accumulate over a period of time.) Examine the location of the incident and identify factors associated with the incident. Interview other company personnel as needed to determine root causes. Document the investigation and recommendations.

A7.3 The final report should include:

A7.3.1 A summary outlining the basic facts of the incident,
A7.3.2 A narrative detailing the circumstances of the casualty or near incident,
A7.3.3 Analysis and comment that lead to logical conclusions or findings, establishing all the factors, including root cause(s) that contributed to the incident, and
A7.3.4 Immediate and long-term recommendations aimed at preventing similar accidents and correcting root causes.

A7.4 It may be helpful to categorize investigation data. An example of a one-page form divided into information categories is provided (Fig. A7.1). Additional pages might be used to capture the summary, narrative, analysis, and recommendations (Fig. A7.2).

A7.5 The information in this annex was drawn from the references below. Further guidance regarding accident investigation may be obtained from IMO A.849 (20) and Refs (6 and 7).
FIG. A7.1 Data Form

<table>
<thead>
<tr>
<th>Vessel Name:</th>
<th>Type of Vessel:</th>
<th>Class. Society:</th>
<th>Vessel Location:</th>
<th>Temp:</th>
<th>Wind Spd:</th>
<th>Sea State:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Vessel operation at time of incident:**
- discharging cargo
- gas freeing tanks
- cleaning tanks
- mooring at dock
- transit harbor
- resource exploration
- trawling

**Employee Name:** Employee ID No.: 

**Employee Position on Vessel:**
- Deck Crew
- Engineering Crew
- Master
- Tankerman
- OIM
- Passenger
- Longshore/harbor worker

**Nature of fatality, injury or illness:**
- Allergic rxn
- Chemical burn
- Electric burn (shock)
- Abrasion
- Blister
- Cut
- Fracture
- Infectious D/s.
- Other

**Part of body injured:**
- Back
- Chest
- Groin
- Knee
- Shoulder
- Multiple Inj

**Location when injured/at time of wear miss:**
- Aft area
- Pump room
- Deck, open
- Fire room
- Fwd area
- Machinery spaces
- Quarters
- Void
- Mud pit

**Root cause(s):**
- Management, Commitment
- Employee Involvement
- Hazard, id, eval, control
- Training

**Signature Lead Investigator:** Date: 
**Signature:** Captain/PIC: Date: 

**Lead Investigator:** Captain/PIC: 

**Related Vessel Casualty:**
- Allision
- Collision
- Strand/grounding
- Failure: hull, water
- Other:

**Nature of Accident or Incident:**
- slip/fall-stairs
- slip/fall-deck
- fall, same level
- struck, falling object
- struck, moving obj.
- struck, vessel
- pinch/crushed
- sprain/strain
- caught in lines
- burned, electric
- hypothermia
- diving accident
- hyperthermia
- acute toxic exposure
- disappeared

**Activity person undertaking when accident occurred:**
- Deck duty
- Drilling
- Handling cargo
- Operating machinery

**Proximate and contributory cause(s) of accident or incident:**
- Intoxication, alcohol
- Intoxication, narcotics
- Adverse weather
- Command problem
- Excessive task/wk load
- Inappropriate policy
- Carelessness
- Cognitive function error
- Fatigue
- Inaccurate info flow
- Design-emergency sys's
- Design-work station
- Physical factors
- Deck slippery
- Failure-use PFD

**Other:**
- Chemical rxn or release
- No/Inad. PPE available
- Improper maintenance
- Improper supervision
- Improper lighting
- Improper load/storage

**FIG. A7.1 Data Form**
Statement of ☐ Injured/Ill Person, ☐ Witness, ☐ Supervisor, ☐ Investigator

(Attach extra sheets, drawings, information if needed.)

Name: (Print)        Signature:        Date:

FIG. A7.2 Statement Form
A8. SYSTEMATIC SHIPBOARD OCCUPATIONAL HEALTH AND SAFETY PROGRAM EVALUATION

A8.1 Tools that may help with program evaluation include:

A8.1.1 Trend analysis of fatality, injury, illness, and “near miss” incident statistics,
A8.1.2 Trend analysis of records of “unsafe acts or behaviors”,
A8.1.3 Review of vessel safety committee reports and recommendations, and
A8.1.4 Review of hazardous condition notifications and abatement actions.

A8.2 Performance measures that may assist in program evaluation include:

A8.2.1 Lost time incident rate,
A8.2.2 Fatality rate,
A8.2.3 Acute toxic exposure incidents per 1000 employee work hours,
A8.2.4 Number of nonconformities with standard operating procedures per 100 employee work hours,
A8.2.5 Percentage of training required by SOHSP completed on schedule,
A8.2.6 Percentage of annual respiratory fit testing completed on schedule, and
A8.2.7 Percentage of annual medical monitoring exams completed on schedule.

A8.3 The audit tool may be used to evaluate a SOHSP. The elements scored in the audit tool are the first seven elements of a SOHSP. Some elements are further divided into factors that are individually scored. The auditor should objectively score the vessel’s SOHSP on each of the individual factors and elements after obtaining the necessary information to do so.

A8.4 Calculate the overall SCORE, as follows:

A8.4.1 Score each element:
A8.4.1.1 The score for the Management Commitment and Leadership Element is the lower of the two scores of the General and Implementation Factors.
A8.4.1.2 The score for the Employee Participation Element is the lower of the two scores for the General and Hazard Reporting Factors.
A8.4.1.3 The score for the Hazard Anticipation, Identification, Evaluation and Control Element is the average of all six factors.
A8.4.1.4 The scores for single-factor elements are the scores for the factor.

The overall SCORE is the average score of the seven element scores and may be assigned a “verbal” description based upon the score.

<table>
<thead>
<tr>
<th>SCORE</th>
<th>Level of Shipboard Occupational Health and Safety Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Outstanding program</td>
</tr>
<tr>
<td>4</td>
<td>Superior program</td>
</tr>
<tr>
<td>3</td>
<td>Basic program</td>
</tr>
<tr>
<td>2</td>
<td>Developmental program</td>
</tr>
<tr>
<td>1</td>
<td>No program or ineffective program</td>
</tr>
<tr>
<td>Program Element</td>
<td>Absent or Ineffective(1)</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td><strong>Management Commitment</strong></td>
<td></td>
</tr>
<tr>
<td><strong>And Leadership</strong></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Implementation</td>
<td></td>
</tr>
<tr>
<td>Overall Score for element</td>
<td>Lowest of 2 Sections</td>
</tr>
<tr>
<td><strong>Employee Participation</strong></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Hazard Reporting</td>
<td>Lowest of 2 Sections</td>
</tr>
<tr>
<td><strong>Hazard Anticipation, Identification, Evaluation, &amp; Control</strong></td>
<td></td>
</tr>
<tr>
<td>Anticipation, Identification, &amp; Evaluation</td>
<td></td>
</tr>
<tr>
<td>Control - General</td>
<td></td>
</tr>
<tr>
<td>Control - Maintenance</td>
<td></td>
</tr>
<tr>
<td>Control - Medical Program</td>
<td></td>
</tr>
<tr>
<td>Control - Emergency Prep-Planning &amp; Drills</td>
<td></td>
</tr>
<tr>
<td>Control - Emergency Prep-First Aid</td>
<td></td>
</tr>
<tr>
<td>Overall Score for element</td>
<td>Average of 6 sections</td>
</tr>
<tr>
<td><strong>Safety and Health Training</strong></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Overall Score for element</td>
<td>Score of 1 section</td>
</tr>
<tr>
<td><strong>Record Keeping</strong></td>
<td></td>
</tr>
<tr>
<td>Data Collection and Analysis</td>
<td></td>
</tr>
<tr>
<td>Overall Score for element</td>
<td>Score of 1 section</td>
</tr>
<tr>
<td><strong>Contract and Third Party Personnel</strong></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Overall Score for element</td>
<td>Score of 1 section</td>
</tr>
<tr>
<td><strong>Fatality, Injury, Illness &amp; Accident Investigation</strong></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Overall Score for element</td>
<td>Score of 1 section</td>
</tr>
<tr>
<td><strong>Overall Program Score</strong></td>
<td>Average of 7 Elements Rounded</td>
</tr>
</tbody>
</table>

**Note:** Tables A8.1-A8.14 provide the verbal descriptions anchoring the numeric indicators in Fig. A8.1.

**FIG. A8.1 Evaluation Form**
TABLE A8.1 Management Commitment and Leadership

<table>
<thead>
<tr>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management commitment and leadership is a precondition for an effective SOHSP.</td>
</tr>
</tbody>
</table>

1. Management demonstrates no policy, goals, objectives, or interest in safety and health issues on this vessel.
2. Management sets and communicates safety and health policy and goals, but remains detached from all other safety and health efforts.
3. Management follows all safety and health rules and gives visible support to the safety and health efforts of others.
4. Management participates in significant aspects of the site’s safety and health program, such as site inspections, incident reviews, and program reviews. Incentive programs that discourage reporting of accidents, symptoms, injuries, or hazards are absent. Other incentive programs may be present.
5. Site safety and health issues are regularly included on agendas of management operations meetings. Management clearly demonstrates—by involvement, support, and example—the primary importance of safety and health for everyone on the work site. Performance is consistent and sustained or has improved over time.

TABLE A8.2 Management Commitment and Leadership

<table>
<thead>
<tr>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources:</td>
</tr>
<tr>
<td>• budget</td>
</tr>
<tr>
<td>• information</td>
</tr>
<tr>
<td>• expertise/training</td>
</tr>
<tr>
<td>• personnel</td>
</tr>
<tr>
<td>Defined and assigned responsibilities</td>
</tr>
<tr>
<td>Commensurate authority to carry out responsibilities</td>
</tr>
<tr>
<td>Accountability</td>
</tr>
</tbody>
</table>

1. Tools to implement a safety and health program are inadequate or missing.
2. Some tools to implement a safety and health program are adequate and effectively used; others are ineffective or inadequate. Management assigns responsibility for implementing a site safety and health program to identified person(s). Management’s designated representative has authority to direct abatement of hazards that can be corrected without major capital expenditure.
3. Tools to implement a safety and health program are adequate, but are not all effectively used. Management representative has some expertise in hazard recognition and applicable standards. Management keeps or has access to applicable standards on the unit and seeks appropriate guidance for interpretation of the standards. Management representative has authority to order/purchase safety and health equipment.
4. All tools to implement a safety and health program are more than adequate and effectively used. Written safety procedures, policies, and interpretations are updated based on reviews of the safety and health program. Safety and health expenditures, including training costs and personnel, are identified in the vessel budget. Hazard abatement is an element in management (officers/persons in charge/supervisors) performance evaluation.
5. All tools necessary to implement a good safety and health program are more than adequate and effectively used. Management safety and health representative has expertise appropriate to vessel size and operation and has access to professional advice when needed. Safety and health budgets and funding procedures are reviewed periodically for adequacy.

TABLE A8.3 Employee Participation

<table>
<thead>
<tr>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee participation provides the means through which those who actually do the work identify hazards, recommend and monitor abatement, and otherwise participate in their own protection.</td>
</tr>
</tbody>
</table>

1. Worker participation in workplace safety and health concerns is not encouraged. Incentive programs are present that have the effect of discouraging reporting of incidents, injuries, potential hazards, or symptoms. Employees/employee representatives are not involved in the shipboard health and safety program.
2. Workers and their representatives can participate freely in safety and health activities on the unit without fear of reprisal. Procedures are in place for communication between employer and workers on safety and health matters. Workers are able to refuse or stop work that they reasonably believe involves imminent danger. Workers are paid while performing safety activities.
3. Workers and their representatives are involved in the safety and health program, involved in inspection of work areas, and are permitted to observe monitoring and receive results. Workers and representatives have access to information regarding the shipboard health and safety program including health and safety data trend analysis, job task analysis, and industrial hygiene sampling data. A documented procedure is in place for raising complaints of hazards or discrimination and receiving timely employer response.
4. Workers and their representatives participate in workplace analysis, inspections and investigations, and development of control strategies throughout the vessel, and have necessary training and education to participate in such activities. Workers and their representatives have access to all pertinent health and safety information, including safety reports and audits. Workers are informed of their right to refuse job assignments that pose serious hazards to them pending management response.
5. Workers and their representatives participate fully in development of the safety and health program and conduct of training and education. Workers participate in audits, program reviews conducted by management or third parties, and collection of samples for monitoring purposes, and have necessary training and education to participate in such activities. Employer encourages and authorizes employees to stop activities that present potentially serious safety and health hazards.

TABLE A8.4 Employee Participation

<table>
<thead>
<tr>
<th>Hazard Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>A reliable hazard reporting system enables employees, without fear of reprisal, to notify management of conditions that appear hazardous and to receive timely and appropriate responses.</td>
</tr>
</tbody>
</table>

1. No formal hazard reporting system exists, or employees are reluctant to report hazards.
2. Employees are instructed to report hazards to management. Supervisors are instructed and are aware of a procedure for evaluating and responding to such reports. Employees use the system with no risk of reprisals.
3. A formal system for hazard reporting exists. Employee reports of hazards are documented, corrective action is scheduled, and records maintained.
4. Employees are periodically instructed in hazard identification and reporting procedures. Management conducts surveys of employee observations of hazards to ensure that the system is working. Results are documented.
5. Management responds to reports of hazards in writing within specified time frames. The workforce readily identifies and self-correction of hazards; they are supported by management to do so.
Anticipation, identification, and evaluation of hazards involves systematic review of vessel and equipment design, review of the vessel and equipment fitness for current conditions and operations, a procurement system that requires consideration of health and safety aspects of items ordered, vessel inspections, exposure assessments, job safety analyses, mechanisms for employees to report hazardous conditions, and review of health and safety data and records to identify trends.

1. No system or requirement exists for hazard review of planned/changed/new equipment or operations. There are no requirements to consider health and safety aspects of items purchased for the vessel. There is no evidence of comprehensive inspections for safety or health hazards, exposure assessments, routine job safety analysis, or health and safety data trend analysis.

2. The person-in-charge of operation and/or equipment changes considers health and safety implications of the changes but has not had appropriate training to be able to identify all health and safety consequences of the changes. The person responsible for procurement considers health and safety issues but has not been trained on hazards that may be encountered. Inspections for health and safety hazards are conducted by vessel and corporate personnel but only in response to accidents or complaints. The employer has identified principle health and safety standards appropriate for the vessel. Supervisors dedicate time to observing work practices and other safety and health conditions in work areas where they have responsibility.

3. Competent person(s) determine health and safety consequences of proposed changes in high-hazard operations or equipment before the changes occur and appropriate precautions are implemented. Competent person(s) determine health and safety hazards of all items procured and appropriate precautions are taken when the item is used. Vessel and corporate personnel with specific training in health and safety hazards conduct vessel inspections. Inspections in need of correction are documented. Inspections include compliance with relevant regulations, industry standards, and practices. Time periods for corrections are set. Current hazard analyses are written (where appropriate) for all high-hazard jobs and processes; analyses are communicated to and understood by affected employees. Hazard analyses are conducted for jobs/tasks/workstations where injury or illnesses have been reported.

4. Competent person(s) in consultation with a qualified professional determines health and safety consequences of all proposed changes in operations or equipment before the changes occur, and appropriate precautions are implemented. Competent person(s) determine health and safety hazards of all items requested for procurement, identify appropriate substitutions for hazardous items, or ensure appropriate precautions are taken if a substitute cannot be identified. A qualified professional conducted a vessel inspection within the last five years, and competent person(s), trained in items identified by the qualified professional, conduct periodic inspections and appropriate corrective actions are taken promptly. The inspections are planned, with key observations or check points defined and results documented. Corrections are documented through followup inspections. Results are available to workers. Current hazard analyses are documented for all work areas and are communicated and available to all employees.

5. Qualified professionals in consultation with certified safety and health professional(s) analyze health and safety consequences of all proposed changes in operations or equipment, identify substitutions if possible, or ensure appropriate precautions are implemented as the change occurs. Competent person(s) in consultation with qualified professional(s) or certified safety and health professional(s), as needed, identify health and safety hazards of all items requested for procurement and obtain substitutes for hazardous items. Regular inspections are planned and overseen by certified safety or health professionals. Statistically valid random audits of compliance with all elements of the shipboard health and safety program are conducted. Observations are analyzed to evaluate progress. Documented workplace hazard evaluations are conducted by certified safety and health professional(s). Corrective action is documented and hazard inventories are updated.

### TABLE A8.5 Hazard Anticipation, Identification, Evaluation, and Control

<table>
<thead>
<tr>
<th>Anticipation, Identification, and Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workforce exposure to all current and potential hazards should be prevented or controlled by using engineering controls whenever feasible and appropriate, work practices and administrative controls, and personal protective equipment.</td>
</tr>
</tbody>
</table>

1. No preventive maintenance program is in place; breakdown maintenance is the rule.

2. There is a preventive maintenance schedule, but it does not cover everything and may be allowed to slide or performance is not documented. Safety devices on machinery and equipment are generally checked before each shift.

3. A preventive maintenance schedule is implemented for areas where it is most needed; it is followed under normal circumstances. Manufacturers’ and industry recommendations and consensus standards for maintenance frequency are followed. Breakdown repairs for safety-related items are expedited. Safety device checks are documented. Ventilation system function is observed periodically.

4. The employer has effectively implemented a preventive maintenance schedule that applies to all equipment. Vessel experience is used to improve safety-related preventative maintenance scheduling.

5. There is a comprehensive safety and preventive maintenance program that maximizes equipment reliability.
TABLE A8.8 Hazard Anticipation, Identification, Evaluation, and Control

Control—Medical Program

An effective shipboard health and safety program will include a suitable medical program where it is appropriate for the nature of the hazards.

1. Management is unaware of, or unresponsive to occupational medical surveillance needs. Required medical surveillance, monitoring, and reporting are absent or inadequate.

2. Required medical surveillance, monitoring, removal, and reporting responsibilities for applicable standards are assigned and carried out, but results may be incomplete or inadequate.

3. Medical surveillance, removal, monitoring, and reporting comply with applicable standards. Employees report early signs/symptoms of job-related injury or illness and receive appropriate treatment.

4. Health care providers provide followup on employee treatment protocols and are involved in hazard identification and control on the vessel. Medical surveillance addresses conditions not covered by specific standards. Employee concerns about medical treatment are documented and responded to.

5. Health care providers periodically observe the work areas and activities and are fully involved in hazard identification and training.

TABLE A8.9 Hazard Anticipation, Identification, Evaluation, and Control

Control—Emergency Preparedness—Planning and Drills

There should be appropriate planning, training/drills, and equipment for response to emergencies.

1. Little or no effort to prepare for emergencies.

2. Emergency response plans for fire, chemical, and weather emergencies as required by regulation are present. Training is conducted as required by the applicable regulation. Some deficiencies may exist.

3. Persons with specific training have prepared emergency response plans. Appropriate alarm systems are present. Employees are trained in emergency procedures. The emergency response extends to spills and incidents in routine operation. Adequate supply of spill control and PPE appropriate to hazards on site is available.

4. Abandoned ship drills are conducted in accordance no less than annually. The plan is reviewed by a qualified safety and health professional.

5. Vessel personnel with emergency response assignments have adequate training. All potential emergencies have been identified. Emergency response plans and performance are reevaluated at least annually and after each significant incident. Procedures for terminating an emergency response condition are clearly defined.

TABLE A8.10 Hazard Anticipation, Identification, Evaluation, and Control

Control—Emergency Preparedness—First Aid

First aid/emergency care should be readily available to minimize harm if an injury or illness occurs.

1. First aid/emergency care cannot be ensured.

2. First aid/emergency care is available on every shift.

3. Personnel with appropriate first aid skills commensurate with likely hazards on the vessel and as required by applicable regulations are available. Management documents and evaluates response time on a continuing basis.

4. Personnel with certified first aid skills are always available on-site; their level of training is appropriate to the hazards of the work being done. Adequacy of first aid is formally reviewed after significant incidents.

5. Personnel trained in advanced first aid and/or emergency medical care are always available on-site.

TABLE A8.11 Safety and Health Training

General

Safety and health training should cover the safety and health responsibilities of all personnel who work on the vessel or affect its operations. It is most effective when incorporated into other training about performance requirements and job practices. It should include all subjects and areas necessary to address the hazards on the vessel.

1. Vessel personnel depend on experience and peer training to meet needs. Master/person-in-charge/others in supervisory positions demonstrate little or no involvement in safety and health training responsibilities.

2. Some orientation training is given to new hires. Some safety training materials (for example, pamphlets, posters, videotapes) are available or are used periodically at safety meetings, but there is little or no documentation of training or assessment of worker knowledge for a given topic. Masters/persons-in-charge/and others in supervisory positions generally demonstrate awareness of safety and health responsibilities, but have limited training themselves or involvement in the site’s training program.

3. Training includes regulatory rights and access to information. Training required by regulations is provided to all vessel employees. Supervisors attend training in all subjects provided to employees under their direction. Vessel personnel can generally demonstrate the skills/knowledge necessary to perform their jobs safely. Records of training are kept and training is evaluated to ensure it is effective.

4. Knowledgeable persons conduct safety and health training that is scheduled, assessed, and documented, and addresses all necessary technical topics. Employees are trained to recognize hazards, violations of regulations, and vessel practices. Employees are trained to report violations to management. Training is followed up with performance observation and feedback. All site employees—including supervisors and masters/persons-in-charge—can demonstrate preparedness for participation in the overall safety and health program. There are easily retrievable scheduling and record keeping systems.

5. Knowledgeable persons conduct safety and health training that is scheduled, assessed, and documented. Training covers all necessary topics and situations, whether addressed in regulations or not, and includes all persons on the vessel (unlicensed personnel to the master or person-in-charge, contractors, and temporary employees). Employees participate in creating site-specific training methods and materials. Employees are trained to recognize inadequate responses to reported program violations. Retrievable recordkeeping system provides for appropriate retraining, makeup training, and modifications to training as the result of evaluations.
### TABLE A8.12 Record Keeping

Data Collection and Analysis

An effective shipboard occupational health and safety program will collect and analyze injury, illness, and “near miss” incident data for indications of sources and locations of hazards, and jobs that experience higher numbers of incidents. By analyzing injury, illness, and “near miss” incident trends over time, patterns with common causes can be identified and prevented.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Little or no collection and/or analysis of injury, illness, or “near miss” incident data. Exposure monitoring is not conducted or documented.</td>
</tr>
<tr>
<td>2</td>
<td>Injury, illness, and “near miss” incident data is collected and analyzed, but not widely used for prevention. CG-2692 is completed for all reportable marine casualties. Exposure records and analysis are organized and available to safety personnel.</td>
</tr>
<tr>
<td>3</td>
<td>Injury, illness, and “near miss” incident logs and exposure records are kept, are audited by shoreside management personnel, and are essentially accurate and complete. Rates are calculated so as to identify high-risk areas and jobs. Liability claims are analyzed and the results are used in the program. Significant analytical findings are used for prevention.</td>
</tr>
<tr>
<td>4</td>
<td>Shoreside management and vessel master/person-in-charge and supervisors can identify the frequent and most severe problem areas, the high-risk areas and job classifications, and any exposures that exceed OSHA PELs, ACGIH TLVs, or company standards. Data are fully analyzed and effectively communicated to employees. Injury, illness, and “near miss” incident data are audited and certified by a responsible person.</td>
</tr>
<tr>
<td>5</td>
<td>All levels of management and the workforce are aware of results of data analyses and resulting preventive activity. External audits of accuracy of injury, illness, and “near miss” incident data, including review of all available data sources are conducted. Scientific analysis of health information, including nonoccupational databases is included where appropriate in the program.</td>
</tr>
</tbody>
</table>

### TABLE A8.13 Contract and Third Party Personnel

General

An effective safety and health program protects all personnel on the vessel, including the employees of contractors, subcontractors, and third party personnel. It is the responsibility of shoreside management and the vessel master or person-in-charge to address contractor safety and third party safety.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shoreside management and the vessel master or person-in-charge make no provision to include contractors and third party personnel within the scope of the vessel’s health and safety program.</td>
</tr>
<tr>
<td>2</td>
<td>Vessel safety policy requires contractor and third party personnel to conform to applicable regulations and other legal requirements.</td>
</tr>
<tr>
<td>3</td>
<td>The master/person-in-charge designates a representative to monitor contractor and third party safety and health practices, and that individual has authority to stop contractor practices that expose host or contractor employees to hazards. Management informs contractor and employees of hazards present at the facility.</td>
</tr>
<tr>
<td>4</td>
<td>Shoreside management investigates a contractor’s safety and health record as one of the bidding criteria. Shoreside management contacts third party personnel management if necessary to correct unsafe third party behavior.</td>
</tr>
<tr>
<td>5</td>
<td>The vessel’s health and safety program ensures protection of everyone employed at the work site including full-time employees, temporary employees, contractors, and third party personnel.</td>
</tr>
</tbody>
</table>
**APPENDIX**

(Nonmandatory Information)

**X1. RATIONALE**

X1.1 This guide was developed by a group of management, labor, and government people involved in the shipping industry. Members of the group agreed that guidance in the area of occupational health and safety would be helpful to the shipping industry. However, they did not want a detailed prescriptive standard, nor did they want to produce something that already existed. The group researched existing guidance at the national and international levels and came to the agreement that research existed that outlined key elements to effective health and safety program implementation. These key elements are contained in this guide with amplifying information specifically geared toward the shipping industry. The literature used in development of the guide is listed in the Reference Section (1-7).

6 The boldface numbers given in parentheses refer to a list of references at the end of the text.

**REFERENCES**


(2) *How to Write an Accident Prevention Program*, State of Washington Department of Labor and Industries, 1996 (Draft).


1. Scope

1.1 This specification covers the requirements for electrical liquid level indicating equipment for shipboard low pressure and high pressure tanks containing freshwater, feed water, potable water, seawater, wastewater, diesel fuel, lubricating oil, contaminated oil, refrigerants, JP fuels, and various other fluids. Application includes compensating tanks in which the equipment must locate the interface.

1.2 Each liquid level indicating equipment typically consists of the following components:

(a) One or more sensing devices;
(b) Flexible interconnections, if needed;
(c) Primary indicator panel assembly;
(d) Auxiliary indicator panel assembly, when required; and
(e) Portable indicator panel assembly, when required.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only. Where information is to be specified, it shall be stated in SI units.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.5 Special requirements for naval shipboard applications are included in the Supplement to this standard.

2. Referenced Documents

2.1 ASTM Standards:
D 3951 Practice for Commercial Packaging

2.2 ISO Standards:
9001 Quality System Model for Quality Assurance in Design/Development, Production, Installation, and Servicing

3. Terminology

3.1 Definitions:

3.1.1 hysteresis—maximum difference in output, at any measurand value within the specified range, when the value is approached first with increasing and then with decreasing measurand.

3.1.2 insulation resistance—the resistance measured between insulated portions of a liquid level indicating equipment and between insulated portions of a liquid level indicating equipment and ground when a specified dc voltage is applied under specified conditions.

3.1.3 output—electrical or numerical quantity, produced by a liquid level indicating sensor or measurement system, that is a function of the applied measurand.

3.1.4 pressure cycling—the specified minimum number of specified periodic pressure changes over which a liquid level indicating sensor will operate and meet the specified performance.

3.1.5 process medium—the measured fluid (measurand) that comes in contact with the sensing element.

3.1.6 repeatability—ability of a liquid level indicating equipment to reproduce output readings when the same measurand value is applied to it consecutively, under the same conditions, and in the same direction.

3.1.7 response—the measured output of a liquid level indicating sensor to a specified change in measurand.

3.1.8 signal conditioner—an electronic device that makes the output signal from a sensor element compatible with a readout system.

3.1.9 wetted parts—liquid level indicating equipment components with at least one surface in direct contact with the process medium.

4. Designation

4.1 Designation—Most liquid level indicating equipment manufacturers use designations or systematic numbering or identifying codes.

4.2 Design—Liquid level indicating equipment typically consist of a sensing device that may or may not be in contact with the process medium, a transduction element that modifies the signal from the sensing device to produce an electrical output, and an indicator panel assembly to show the level of the medium being measured. Some parts of the sensing device may be hermetically sealed if those parts are sensitive to and may be exposed to moisture. The output cable must be securely fastened to the body of the sensing device. A variety of sensing
4.2.1 Sensing Techniques—The sensing device typically does not use any part of the tank structure as part of the sensing device.

4.2.1.1 Admittance and Impedance—The admittance and impedance sensing technique uses the apparent resistance to the current flow of an alternating current in the sensing device circuit or its reciprocal with respect to the level of the measured fluid in the tank.

4.2.1.2 Magnetic Float—The magnetic float sensing technique uses a float with embedded magnets to change the circuit status of the sensing device and produce an electrical signal proportional to the float’s position with respect to the level of the measured fluid in the tank.

4.2.1.3 Differential Pressure—The differential pressure-sensing technique uses the pressure difference regardless of the ambient pressure to change the circuit status of the sensing device and produce an electrical signal proportional to the level of the measured fluid in the tank.

4.2.1.4 Time Domain Reflectometry—The time domain reflectometry sensing technique uses a high frequency electromagnetic wave transmitted along a transmission line, wire, cable, or rod to determine the level of the measured liquid(s) by detecting changes in and timing the reflected energy.

4.2.1.5 Capacitive—The capacitive-sensing technique uses the change in capacitance of the sensing device to produce an electrical signal proportional to the level of the measured fluid in the tank.

4.2.1.6 Resistance Tape—The resistance-tape-type sensing technique uses the change in circuit resistance in the sensing device to produce an electrical signal proportional to the level of the measured fluid in the tank.

4.2.1.7 Static Pressure—The static head technique measures the static (head) pressure caused by the measured liquid relative to the ambient pressure to change the circuit status of the sensing device and produce an electrical signal proportional to the level of the measured fluid in the tank.

4.2.1.8 Radar—The radar technique uses a high frequency electromagnetic wave transmitted through the air, including guided inside a hollow tube, to determine the level of the measured liquid(s) by detecting changes in and/or timing the reflected energy.

4.2.1.9 Ultrasonic—The ultrasonic technique uses high frequency sonic waves transmitted either through the air or in the liquid to be measured, to determine the measured liquid(s) level by detecting changes in and/or timing the reflected energy.

4.3 Process Medium—The following are the most common types of process media. The first column identifies fluids that are measured in the tank. The second column identifies the liquid or gas that interfaces with the measured fluid.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Liquid or Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contaminated fuel</td>
<td>air</td>
</tr>
<tr>
<td>Contaminated oil</td>
<td>compressed air</td>
</tr>
<tr>
<td>Fuel (diesel fuel, cargo fuel, gasoline)</td>
<td>compressed gas</td>
</tr>
<tr>
<td>Freshwater, potable water, feed water</td>
<td>Water</td>
</tr>
<tr>
<td>Hydraulic oil</td>
<td>steam</td>
</tr>
<tr>
<td>JP-5, JP fuels</td>
<td>seawater</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>wastewater</td>
</tr>
<tr>
<td>Refrigerants</td>
<td></td>
</tr>
<tr>
<td>Synthetic oil</td>
<td></td>
</tr>
<tr>
<td>Seawater</td>
<td></td>
</tr>
<tr>
<td>Turbine oil</td>
<td></td>
</tr>
<tr>
<td>Waste oil</td>
<td></td>
</tr>
<tr>
<td>Wastewater, sanitary waste</td>
<td></td>
</tr>
</tbody>
</table>

4.4 Pressure Range—The liquid level indicating equipment must be able to withstand the expected fluid pressures in the tank. Pressure range specification must take into account expected pressures to be encountered in differing tank sizes and fluid types for a particular sensor type.

4.5 Display—The display for liquid level indication is typically specified as analog, digital, or both.

5. Ordering Information

5.1 The purchaser shall provide the manufacturer with all of the pertinent application data shown in accordance with 5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

5.2 Acquisition Requirements—Acquisition documents must specify the following:

(a) Title, number, and date of this specification;
(b) Manufacturer’s part number;
(c) Sensing technique;
(d) Application;
(e) Pressure range;
(f) Display requirements (see 4.5) and indication range;
(g) Indicator panel assembly mounting method;
(h) Indicator panel assembly requirements;
(i) System operating characteristics;
(j) Materials;
(k) Environmental requirements;
(l) Quantity of liquid level indicating equipment required;
(m) Size and weight restrictions (see 7.5);
(n) Critical service life requirements (see 8.1);
(o) Performance requirements (see 8.2);
(p) Special surface finish requirements (see 9.1);
(q) When certification is required (see Section 13);
(r) Special marking requirements (see Section 14);
(s) Special packaging or package marking requirements (see Section 15);
(t) When ISO 9001 quality assurance system is not required (see 16.1); and
(u) Special warranty requirements (see 16.2).

6. Materials and Manufacture

6.1 Sensing Devices—The materials for the sensing devices and wetted pans shall be selected for long-term compatibility (see 8.1) with the process medium (see 4.3).
6.2 Material Inspection—The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with the specifications and standards as applicable.

7. Physical Properties

7.1 Enclosure—Unique or special enclosure requirements shall be specified in the acquisition requirements (see 5.2).

7.2 Liquid Level Indicating Equipment Mounting—Liquid level indicating equipment is commonly mounted using brackets or similar hardware.

7.3 External Configuration—The outline drawing shall show the configuration with dimensions in SI units (inch-pound units). The outline drawing shall include limiting dimensions for electrical connections if required. The outline drawing shall indicate the mounting method with hole size, center location, and other pertinent dimensions. Where threaded holes are used, thread specifications shall be provided.

7.4 Electrical Connection—Electrical flexible interconnections shall be provided with each liquid level indicating sensor as specified in the contract (see 5.1).

7.5 Size and Weight—The user may have intended applications in which size and weight are limited. Size and weight restrictions shall be specified in the acquisition requirements (see 5.2).

8. Performance Requirements

8.1 Service Life—The user may have a minimum specified service life requirement that may be critical. Critical service life requirements shall be specified in the acquisition requirements (see 5.2).

8.2 Liquid Level Indicating Equipment Performance—Performance tolerances are usually specified in percent of indicator full scale. Critical performance requirements shall be specified in the acquisition requirements (see 5.2). The following performance characteristics and environmental exposures may or may not be important to each user’s intended application.

- Accuracy
- Response time
- Repeatability
- Hysteresis
- Insulation resistance
- Specific gravity
- Fluid conductivity
- Tank wall proximity
- Inclination
- Spike voltage
- Salt spray
- Pressure
- Vibration
- Shock
- Enclosure
- dc magnetic field
- Electromagnetic interference (EMI)
- Immersion
- Supply line voltage and frequency variation

9. Workmanship, Finish, and Appearance

9.1 Finish and Appearance—Any special surface finish and appearance requirements shall be specified in the acquisition requirements (see 5.2).

10. Inspection

10.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

(a) First article tests (see 10.2) and
(b) Conformance tests (see 10.3).

10.2 First Article Tests—First article test requirements shall be specified, where applicable. First article test methods should be identified for each design and performance characteristic specified. Test report documentation requirements should also be specified.

10.3 Conformance Tests—Conformance testing is accomplished when first article tests were satisfied by a previous acquisition or the product has demonstrated reliability in similar applications. Conformance tests are usually less intensive than first article tests, often verifying that samples of a production lot meet a few critical performance requirements.

11. Number of Tests and Retests

11.1 Test Specimen—The number of test specimens to be subjected to first article tests shall be specified and should depend on the liquid level indicating equipment design. Generally, one liquid level indicating equipment of each type (that is, sensing technique, application, pressure range, display, and indication range) shall be subjected to first article testing.

12. Test Data

12.1 Test Data—Test data shall remain on file at the manufacturer’s facility for review by the buyer upon request. It is recommended that test data be retained in the manufacturer’s files for at least three years or a period of time acceptable to the buyer and manufacturer.

13. Certification

13.1 When specified in the acquisition requirements (see 5.2), the buyer shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

14. Product Marking

14.1 User specified product marking shall be listed in the acquisition requirements (see 5.2). The minimum data to be clearly marked on each liquid level indicating equipment shall include the following:

(a) Manufacturer’s name,
(b) Manufacturer’s part number,
(c) Serial number or lot number,
(d) Date of manufacture (not required if serial number is traceable to date of manufacture), and
(e) Excitation voltage.

15. Packaging and Package Marking

15.1 Packaging of Product for Delivery—Product should be packaged for shipment in accordance with Practice D 3951.
15.2 Any special packaging or package marking requirements for shipment or storage shall be identified in the acquisition requirements (see 5.2).

16. Quality Assurance

16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see 5.2).

16.2 Responsibility for Warranty—Unless otherwise specified, the manufacturer is responsible for the following:
(a) All materials used to produce a unit and
(b) Workmanship to produce the unit.
Special warranty requirements shall be specified in the acquisition requirements (see 5.2).

17. Keywords

17.1 level indicator; liquid level; sensing device; tank level

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard F25(LLIE)M-99 and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supersedes MIL-L-23886, Liquid Level Indicating Equipment (Electrical), for new ship construction.

LIQUID LEVEL INDICATING EQUIPMENT (ELECTRICAL)

S1. Scope

S1.1 This specification supplement covers the requirements for electrical liquid level indicating equipment for use in low pressure and high pressure tanks aboard naval ships containing freshwater, feed water, potable water, seawater, wastewater, diesel fuel, lubricating oil, contaminated oil, refrigerants, JP fuels, and various other fluids.

S1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in SI units.

S2. Reference Documents

S2.1 ABS Rules:
Rules for Building and Classing Steel Vessels
S2.2 ISO Standards:
9001 Quality System—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing
S2.3 Military Standards:
MIL-C-17 Cables, Radio Frequency, Flexible, Coaxial
MIL-C-915 Cable and Cord, Electrical, for Shipboard Use, General Specifications
MIL-C-24231 Connectors, Plugs, Receptacles, Adapters, Hull Inserts, and Hull Insert Plugs, Pressure-Proof, General Specification for
MIL-L-17331 Lubricating Oil, Steam Turbine and Gear, Moderate Service

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
MIL-S-16032 Switches and Detectors, Shipboard Alarm Systems
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of
MIL-STD-1399 Section 070, Interface Standard for Shipboard Systems, D.C. Magnetic Field Environment
MIL-STD-1399 Section 300, Interface Standard for Shipboard Systems, Electric Power, Alternating Current
S2.4 NEMA Standards:
250 Enclosures for Electrical Equipment (1000 V Maximum)

S3. Terminology

S3.1 Terminology is consistent with that of Section 3 and the referenced documents.

S4. Designation

S4.1 Designation—For this specification, liquid level indicating equipment designations shall be assigned as specified in S5.1 and listed in the format below:
Example: F25(LLIE)M-MF-SW/AR-LP-A-005/245/250

<table>
<thead>
<tr>
<th>Specification</th>
<th>MF</th>
<th>SW</th>
<th>AR</th>
<th>LP</th>
<th>A</th>
<th>005/245/250</th>
</tr>
</thead>
<tbody>
<tr>
<td>F25(LLIE)M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>technique</td>
<td>S4.2</td>
<td>S4.3</td>
<td>S4.4</td>
<td>S4.5</td>
<td>S4.6</td>
<td></td>
</tr>
</tbody>
</table>

4 Available from American Bureau of Shipping, 2 World Trade Center, 106th Floor, New York, NY 10048.
5 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
6 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.
7 Available from NEMA, 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
S4.2 Sensing Technique — The sensing technique shall be designated as follows:

<table>
<thead>
<tr>
<th>Fluid Liquid or Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF — Contaminated fuel</td>
</tr>
<tr>
<td>CO — Contaminated oil</td>
</tr>
<tr>
<td>FO — Fuel (diesel fuel, cargo fuel, gasoline)</td>
</tr>
<tr>
<td>FW — Freshwater, potable water, feed water</td>
</tr>
<tr>
<td>HO — Hydraulic oil</td>
</tr>
<tr>
<td>LO — Lubricating oil</td>
</tr>
<tr>
<td>RF — Refrigerants</td>
</tr>
<tr>
<td>SO — Synthetic oil</td>
</tr>
<tr>
<td>SW — Seawater</td>
</tr>
<tr>
<td>TO — Turbine oil</td>
</tr>
<tr>
<td>WO — Waste oil</td>
</tr>
<tr>
<td>WW — Wastewater, sanitary waste</td>
</tr>
</tbody>
</table>

S4.3 Application — The fluid to be measured shall be designated as follows. The first two-letter designation identifies the fluid to be measured in the tank. The second two-letter designation identifies the liquid or gas that interfaces with the measured fluid.

S4.4 Pressure Range — The pressure range under which the sensing device shall operate shall be designated as follows:

<table>
<thead>
<tr>
<th>Pressure Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP — Vacuum pressure of 749-mm mercury (29.5–in. mercury) to 138 kPa (20 psig) inclusive.</td>
</tr>
<tr>
<td>VP — Vacuum pressure of 749-mm mercury (29.5–in. mercury) to 689 kPa (100 psig) inclusive.</td>
</tr>
<tr>
<td>LP — From 0 kPa to 689 kPa (0 to 100 psig) inclusive.</td>
</tr>
<tr>
<td>HP — From 696 kPa (101 psig) to maximum pressure as specified (see S5.2).</td>
</tr>
</tbody>
</table>

S4.5 Display — The display shall be designated as follows:

<table>
<thead>
<tr>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>A — Analog</td>
</tr>
<tr>
<td>D — Digital</td>
</tr>
<tr>
<td>C — Analog and digital</td>
</tr>
</tbody>
</table>

S4.6 Indication Range — The indication range shall be designated by three numbers, separated by a slash. Each number shall represent a height in millimetres above the bottom of the tank. The first number shall indicate where liquid level indication shall begin. The second number shall indicate where liquid level indication shall end. The third number shall indicate the total height of the tank.

S5. Ordering Information

S5.1 The buyer shall provide the manufacturer with all of the pertinent application data in accordance with S5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.

S5.2 Acquisition Requirements — Acquisition documents shall specify the following:

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Title, number, and date of this specification;</td>
</tr>
<tr>
<td>(b) Part designation (see S4.1);</td>
</tr>
<tr>
<td>(c) National Stock Number (NSN) if available;</td>
</tr>
<tr>
<td>(d) Quantity of liquid level indicating equipment required;</td>
</tr>
<tr>
<td>(e) If pressure range is HP, the maximum pressure required (see S4.4);</td>
</tr>
<tr>
<td>(f) If deviation requests are not required when departing from material guidance (see S6);</td>
</tr>
<tr>
<td>(g) If the maximum height of any individual component is other than 3048 mm (120 in.) or maximum weight of any individual component is other than 16 kg (35 lbs) (see S7.6);</td>
</tr>
<tr>
<td>(h) If primary indicator panel assembly is panel or bulkhead mounted (see S7.9);</td>
</tr>
<tr>
<td>(i) If more than one liquid level display is required for the primary indicator panel assembly (see S7.9);</td>
</tr>
<tr>
<td>(j) If volumetric accuracy is required (see S7.9.1);</td>
</tr>
<tr>
<td>(k) If a control circuit is required and whether settings are to be two high, two low, one high and one low, or two high and two low (see S7.9.2);</td>
</tr>
<tr>
<td>(l) If alarm lights are required on primary indicator panel assembly (see S7.9.3);</td>
</tr>
<tr>
<td>(m) If audible alarm and alarm acknowledge switch are required on primary indicator panel assembly (see S7.9.3);</td>
</tr>
<tr>
<td>(n) If a protective shield is required for primary indicator panel assembly (see S7.9.4);</td>
</tr>
<tr>
<td>(o) If auxiliary indicator panel assembly is required. Specify either panel or bulkhead mounted, and what is required in addition to a liquid level display (see S7.10);</td>
</tr>
<tr>
<td>(p) If portable indicator assembly is required (see S7.11);</td>
</tr>
<tr>
<td>(q) If epoxy coating is required (see S7.13);</td>
</tr>
<tr>
<td>(r) If special purpose equipment is not to be provided (see S7.14);</td>
</tr>
<tr>
<td>(s) If indicator dial is not to be furnished blank or if additional information is to be identified on the dial or if dials are to have other than black letters, numerals, and graduations on a white background (see S7.15.1);</td>
</tr>
<tr>
<td>(t) If red illumination is required for liquid level display (see S7.15.2);</td>
</tr>
<tr>
<td>(u) If audible signals are required for any remote station (see S7.16);</td>
</tr>
<tr>
<td>(v) If dc magnetic field strength requirement is other than 400 A/m (see S8.16 and S12.2.15);</td>
</tr>
<tr>
<td>(w) When first article tests are required (see S10.3);</td>
</tr>
<tr>
<td>(x) Sampling and acceptance numbers for Group A and Group B testing (see S11.1 and S11.3);</td>
</tr>
<tr>
<td>(y) If the inclination angle is other than 45° (see S12.2.8);</td>
</tr>
<tr>
<td>(z) Special product marking requirements (see S14);</td>
</tr>
<tr>
<td>(aa) Special packaging or package marking requirements (see S15);</td>
</tr>
<tr>
<td>(bb) When ISO 9001 quality assurance system is not required (see S16.1); and</td>
</tr>
<tr>
<td>(cc) Special warranty requirements (see S16.2).</td>
</tr>
</tbody>
</table>

S5.3 First Article Tests — When first article testing is required, the buyer should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer’s current inventory. The number of items to be tested in accordance with S10.4 should be specified. The buyer should include specific instructions in acquisition documents regarding arrangements for tests, approval of first article test results and time period for approval, and disposition of first
articles. Invitations for bids should provide that the buyer reserves the right to waive the requirement for samples for first article testing to those bidders offering a product which has been previously acquired or tested by the buyer; and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior buyer approval is presently appropriate for the pending contract. The manufacture of items before buyer approval should be specified as the responsibility of the manufacturer.

S6. Materials

S6.1 General—Toxic materials shall not be used in potable water applications.

S6.2 Metals—Unless otherwise specified herein, all metals used in the construction of liquid level indicating equipment shall be corrosion resistant or treated to provide corrosion resistance. Dissimilar metals shall not be used in contact with each other unless suitable finished to prevent electrolytic corrosion. The materials for wetted parts shall be selected for long-term compatibility (see S4.3) with the contacted fluid, liquid, or gas (see S4.3).

S6.3 Flammable Materials—Materials used in the construction of liquid level indicating equipment shall in the end configuration be noncombustible or fire retardant in the most hazardous of atmosphere, pressure, and temperature to be expected in the application. Fire retardance shall not be achieved by use of nonpermanent additives to the material.

S6.4 Fungus-Resistant Materials—Materials used in the construction of liquid level indicating equipment shall not support the growth of fungus.

S6.5 Solvents, Adhesives, and Cleaning Agents—When chemicals or cements are used in bonding of internal components, no degradation shall result during in-service use.

S7. Physical Properties

S7.1 Configuration—Each liquid level indicating equipment shall consist of the following components:
(a) One or more sensing devices,
(b) Flexible interconnections, if needed,
(c) Primary indicator panel assembly,
(d) Auxiliary indicator panel assembly, when required (see S5.2), and
(e) Portable indicator assembly, when required (see S5.2).

S7.2 Magnetic Float Liquid Level Switches—Magnetic float liquid level switches shall be in accordance with MIL-S-16032.

S7.3 Microprocessors—When microprocessors are used to perform processing and control functions, built-in test (BIT) shall be provided in the form of firmware residing in programmable read only memory. To assist troubleshooting, BIT shall indicate basic failure modes of the equipment such as power supply parameters out of tolerance.

S7.4 Testability—No mechanical or electrical disassembly shall be required for the purpose of obtaining access to test points or adjustments, except for removal of a cover plate.

S7.5 Safety—For JP, CF, CO, WO, and FO applications, the portions of the liquid level indicating equipment inside the tank shall be in accordance with the hazardous area requirements of ABS Rules for Building and Classing Steel Vessels, except flexible interconnections shall be in accordance with S7.8.

S7.6 Size and Weight—Unless otherwise specified (see S5.2), the maximum height of any individual component shall be 3048 mm (120 in.). Unless otherwise specified (see S5.2), the maximum weight of any individual component shall be 16 kg (35 lbs).

S7.7 Interchangeability—In no case shall parts be physically interchangeable or reversible unless such parts are also interchangeable or reversible with regard to function, performance, and strength.

S7.8 Flexible Interconnections—Electrical flexible interconnections, including tank penetration cables, shall have high pressure pin connections in accordance with MIL-C-24231 on high pressure tank penetrations. Flexible interconnections shall permit easy repair, replacement, substitution, or bypassing of sensing devices. No interconnection boxes or junction boxes shall be installed inside of any tank. Flexible interconnections shall be Type I or Type II as specified herein.

S7.8.1 Type I Flexible Interconnections—Type I flexible interconnections shall be used in FO, CF, CO, WO, and JP applications. For sensing techniques other than TD, the cable shall be shielded, water-blocked cable consisting of watertight primary conductors, insulated with crosslinked (XL) modified polyvinylidene fluoride. The primary conductors shall be water blocked and wrapped with polyester tape. The cable jacket shall be XL-modified ethylene-tetrafluoroethylene copolymer. The final cable formulation shall meet the physical characteristics as specified in MIL-C-915. For TD sensing techniques, the cable shall be FEP-jacketed coax cable in accordance with MIL-C-17/127.

S7.8.2 Type II Flexible Interconnections—Type II flexible interconnections shall be used in applications other than FO, CF, CO, WO, and JP applications. Type II flexible interconnections shall be of watertight flexing construction in accordance with MIL-C-915 and MIL-C-915/8, Type DSS, TSS, FSS, and 755. The cable outer jacket shall be butadiene copolymer with an acrylonitrile content of 40 ± 10 % by volume. The final cable formulation shall meet the physical characteristics (tensile strength, elongation, bending endurance, and so forth) as specified in MIL-C-915. For TD sensing techniques, the cable shall be FEP-jacketed coax cable in accordance with MIL-C-17/127.

S7.9 Primary Indicator Panel Assembly—The primary indicator panel assembly shall be as small and lightweight as practicable and arranged for bulkhead or panel mounting as specified (see S5.2). Unless otherwise specified (see S5.2), the primary indicator panel assembly shall provide only a single liquid level display. The primary indicator panel assembly shall consist of devices such as regulated power supply, signal conditioners, controls, and indicators required for proper operation. When specified (see S5.2), a control circuit to be used for actuating an external device, such as an alarm or pump, when liquid level reaches predetermined points shall be provided. Other functional components and parts not included in the sensing device assembly shall be contained within the panel enclosure. Where multiple displays are combined on a single primary indicator panel assembly, there shall be no interaction
between the individual tank liquid level indicating equipment circuits except that a common power supply and operational test device may be used.

S7.9.1 Signal Conditioner—The signal conditioner shall provide a continuous output signal from 0 to 200 µAdc, 4 to 20 mAdc, 0 to 10 Vdc, or 1 to 5 Vdc. The signal conditioner output shall be uninterrupted from empty to full or over that portion of the tank to be measured. Unless volumetric accuracy is specified (see S5.2), the output signal shall be proportional to the actual liquid level height in the tank. When volumetric accuracy is specified, the output of the signal conditioner shall be proportional to the actual liquid level volume in the tank, and the contracting activity will furnish the tank capacity curve. Volumetric accuracy shall not be accomplished by modifications to the indicator dial scale or display.

S7.9.2 Control Circuit—When specified (see S5.2), a control circuit shall be provided that has two (two high, two low, or one high and one low), or four (two high and two low) independently adjustable settings, each of which controls a two-pole double throw switching device with a contact rating of 1 A (inductive) at 115 V, 60 Hz.

S7.9.2.1 Control Circuit Setpoints—The high level control circuit setpoints shall be adjustable from 50 to 98% of the indicated range. The low level control circuit setpoints shall be adjustable from 2 to 50% of the indicated range. No mechanical or electrical disassembly shall be required to access the control circuit setpoint adjustments except for removal of a cover plate. A control circuit test means shall be provided to verify the alarm setpoints and control circuit operation.

S7.9.3 Controls and Indicators—The following controls and indicators shall be mounted on the front panel of the primary indicator panel assembly:

(a) Power-on light (white lens),
(b) Power-on switch,
(c) One or more liquid level displays,
(d) Operational test device,
(e) When required, alarm lights (see S5.2), and
(f) When required, audible alarm and alarm acknowledge switch (see S5.2). Multiposition switches and controls may be used to combine functions.

S7.9.4 Protective Shield—The protective shield, when required (see S5.2), shall be rigid, transparent, shatterproof, and positioned as close to the indicator as possible to protect the indicator from accidental damage. The protective shield shall not trap moisture and shall be easily removable.

S7.10 Auxiliary Indicator Panel Assembly—When required (see S5.2), the auxiliary panel enclosure shall be as small and lightweight as practicable and arranged for bulkhead or panel mounting as specified (see S5.2). Unless otherwise specified (see S5.2), only a liquid level display shall be mounted on the front panel. The liquid level display shall be of the same type as on the primary indicator panel assembly. In the event of failure of the auxiliary indicator panel assembly, a device shall be provided on the primary indicator panel assembly to allow isolation of the auxiliary indicator panel assembly. With the auxiliary indicator panel assembly isolated, the primary indicator panel assembly shall continue to operate as specified herein.

S7.11 Portable Indicator Panel Assembly—When required (see S5.2), the portable indicator panel assembly shall meet the requirements of the primary indicator panel assembly (see S7.9), except bulkhead or panel mounting provisions are not required.

S7.12 Mounting—Component mounting devices or brackets shall be supplied with the liquid level indicating equipment.

S7.13 Coating—For all seawater applications and when required (see S5.2), the stationary metallic parts of the liquid level indicating equipment which may come in contact with the fluid to be measured, excluding flexible interconnections, shall be powder epoxy coated.

S7.14 Maintainability—The liquid level indicating equipment shall facilitate assembly, disassembly, fault isolation, operational test (for example, setting or checking alarm setpoints and setting or checking full-scale meter deflection), and preventative maintenance without the aid of special tools or special purpose equipment. Unless otherwise specified (see S5.2), special purpose equipment required for initial setup, equipment change, or troubleshooting shall be provided with the liquid level indicating equipment. Functional pans shall be readily identifiable, accessible, and removable for replacement. If possible, all equipment components, excluding float when used, shall be maintainable outside the tank.

S7.15 Liquid Level Display—Liquid level displays shall be 0 to 200 µAdc, 4 to 20 mAdc, 0 to 10 Vdc, or 1 to 5 Vdc; high impact shock resistant; and watertight or sealed electrical indicating meter types in accordance with one of the following:
(a) 4½ in., 250° with nominal scale length meter;
(b) Panel mounted, edgewise meter;
(c) Digital bargraph-type panel meter with minimum 4-digit display and minimum 51–segment (101–segment preferred) analog display. Light-emitting diode type preferred; and
(d) Digital panel display with 3½ digits graduated 0 to 100% only. Light-emitting diode type preferred.

S7.15.1 Dials—Unless otherwise specified (see S5.2), liquid level display dials shall be furnished blank, except for minimum and maximum travel points. The dial shall be readily removable and replaceable from the front of the liquid level display without disturbing the pointer or other parts of the liquid level display. The dial surface shall be suitable for marking by an installing activity after the liquid level indicating equipment has been calibrated to a particular tank. When graduations are specified, they shall extend uniformly over the full range of the liquid level display and shall be multiples of 1, 2, 5, 10, 20, 50, and so forth. Multiples of any other numbers or fractions are not permitted. The minimum number of graduations per dial shall be 24 and the maximum number of graduations shall be 200. Dials shall begin and end with a numbered graduation. Markings such as “O” and “F” shall not be used. When required (see S5.2), additional information shall be identified on the dial as specified by the contracting activity. Unless otherwise specified (see S5.2), dials shall have black letters, numerals, and gradations on a white background. The indicator pointer shall be black.

S7.15.2 Red Illumination—When red illumination is specified (see S5.2), the primary indicator shall have white letters, numerals, and gradations on a black background and shall
contain internal red illumination. The letters, numerals, and graduations shall appear white under ambient white light and red under ambient and internal red light. The indicator pointer shall be either red illuminated or silhouetted against the dial. Red illuminated dials shall be readable in all levels of incident illumination up to 0.3 lux. The lighting circuit shall be ungrounded and shall be energized from a 6-V supply with separate external terminals.

S7.15.3 Display Visibility—The display shall be clearly visible from a distance of 3 ft and from a viewing angle of 45° from normal, both vertically and horizontally.

S7.16 Audible Signals—When audible signals are required for any remote station (see S5.2), the audible signal shall be actuated by the signal conditioner output or a control circuit adjusted to a predetermined level (see S7.9.1 and S7.9.2).

S8. Performance Requirements

S8.1 Service Life—Electrical liquid level indicating equipment shall be constructed for a life of 25 years of operation.

S8.2 Sensing Device Operation—The sensing device shall not use any part of the tank structure as part of the sensing device.

S8.3, Accuracy

S8.3.1 Liquid Level Indicating Equipment Accuracy—Liquid level indicating equipment accuracy shall be as follows:

(a) Actual liquid level as “height in the tank” or “volume in the tank” (volumetric accuracy), whichever is specified in S5.2, shall be within ±3% of full scale and

(b) Repeatability of the indicators shall be within ±1% of full scale at any point on the scale.

S8.3.2 Control Circuit—Accuracy of adjustable control circuit setpoints shall be as follows:

(a) Hysteresis of dead band make and break of the control function when operated through down and up cycles shall not exceed ±3% including instrument hysteresis and dead band and

(b) Repeatability of the control point contact shall be within ±1% of full scale.

S8.4 Response Time

S8.4.1 Indication Response Time—Liquid level indicating equipment shall have an indication response time of 0.5 s or less for liquid level change rates up to 1 in./s. Indication response time is defined as the time difference between when a liquid achieves a specified level and when the liquid level display indicates that specified level within the accuracy requirements of S8.3.

S8.4.2 Control Circuit Response Time—Control circuit response time shall be adjustable and shall have a minimum control circuit response time of 0.5 s and a maximum control circuit response time of 20 s. The indication response time shall be in accordance with S8.4.1 regardless of control circuit response time setting. Control circuit response time is defined as the time difference between when a liquid reaches a setpoint level and when the control circuit activates or deactivates the switching device associated with that setpoint level. Accuracy shall be in accordance with S8.3.

S8.5 Insulation Resistance—The liquid level indicating equipment insulation resistance shall not be less than 10 MΩ. Accuracy shall be in accordance with S8.3 after measurement of insulation resistance.

S8.6 Specific Gravity—For applications in which the fluid is FO, CO, WO, CF, or JP, accuracy shall be in accordance with S8.3 when subjected to changes in specific gravity. Manual adjustments shall not be permitted or required to obtain accuracy.

S8.7 Fluid Conductivity—For applications in which water of any type is present, accuracy shall be in accordance with S8.3 when the water conductivity is in the range of 3 to 10 000 µS/cm. Manual adjustments shall not be permitted or required to obtain accuracy.

S8.8 Tank Wall Proximity—Accuracy shall be in accordance with S8.3 when the distance from the sensing device to the tank walls is reduced.

S8.9 Inclination—Accuracy shall be in accordance with S8.3 when the liquid level indicating equipment is inclined. Differential pressure sensing devices with ranges less than 20 in. of water may compensate for hydrostatic pressure changes created by the inclined geometry.

S8.10 Spike Voltage—Accuracy shall be in accordance with S8.3 after spike voltage is applied.

S8.11 Accelerated Life (Endurance)—The liquid level indicating equipment shall withstand the effects of the accelerated life test. The temperature range shall be 0 to 60°C except for ST (steam) applications in which the temperature range shall be 0 to 100°C. Performance shall be in accordance with S8.3 throughout the test. After completion of the test and cleaning, the base metal shall not be visible through the finish nor shall there be any evidence of blistering, softening, separation from the base metal, corrosion, or other coating failures. Flexible interconnections shall not exhibit any signs of deterioration nor corrosion of connector pins and housings. Upon completion of the accelerated life tests, accuracy and response time shall be in accordance with S8.3 and S8.4.

S8.11.1 Power Supply—The power supply shall be compatible with Type I power input as specified in MIL-STD-1399, Section 300. Nominal power input voltage and frequency shall be 115 V, 60 Hz, single phase. Changes in input voltage and frequency within ±5% of nominal shall have no deleterious effect on the power supply. Accuracy shall be in accordance with S8.3.

S8.12 Enclosure—Liquid level indicating equipment to be installed partially or totally outside the tank shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures. Portable liquid level indicating equipment shall meet all test criteria in NEMA Standard 250 for Type 6 enclosures. Operation shall be in accordance with S8.3.

S8.13 Pressure—Sensing devices that may be exposed to seawater or the fluid being measured, complete with entrance fittings and interconnection fittings, shall withstand the pressure test without physical or electrical damage and without any leakage or signs of leakage around any of the fittings. Flexible interconnections shall show no evidence of liquid intrusion or evidence of mechanical or electrical damage. Accuracy of all readings shall be in accordance with S8.3 throughout the test and for the postinspection reference measurement.
S8.14  *Vibration*—Liquid level indicating equipment shall show no evidence of mechanical or electrical damage or loosening of pans when subjected to the vibration test. Operating controls shall not change status, and there shall be no transfer of switch contacts during, or as a result of, the vibration test. Accuracy shall be in accordance with S8.3.

S8.15  *Shock*—Liquid level indicating equipment shall show no evidence of mechanical or electrical damage or loosening of pans as a result of shock tests. Operating controls shall not change status, and there shall be no transfer of switch contacts as a result of shock tests. Accuracy shall be in accordance with S8.3.

S8.16  *DC Magnetic Field*—Unless otherwise specified (see S5.2), liquid level indicating equipment shall meet the 400-A/m dc magnetic field environment requirement of MIL-STD-1399, Section 070, Part 1. Accuracy shall be in accordance with S8.3.

S8.17  *Electromagnetic Interference*—The liquid level indicating equipment shall meet the requirements of Table II of MIL-STD-461, except as modified below:

- CE101—The test signal shall be applied only to the ac power leads of the test sample.
- CE 102—The test signal shall be applied only to the ac power leads of the test sample.
- CS114—Only limit Curve #2 shall apply with the frequency range limited to 10 kHz to 30 MHz.
- RE101—Only the limit curve for 50 cm shall apply.
- RS103—The frequency range shall be limited to 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

Accuracy shall be in accordance with S8.3.

S8.18  *Flexible Interconnection*—Type I cables shall resist swelling and show no evidence of liquid intrusion or evidence of mechanical or electrical damage after immersion testing in JP-5. Removable flexible interconnections shall meet the insulation resistance test requirements of S8.5 after completion of immersion testing.

**S9. Workmanship, Finish, and Appearance**

S9.1  After fabrication, parts and assembled equipment shall be cleaned of smudges; loose, spattered, or excess solder; weld metal; metal chips and mold release agents; or any other foreign material that might detract from the intended operation, function, or appearance of the equipment. Wires and cables shall be positioned or protected to avoid contact with rough or irregular surfaces and sharp edges and to avoid damage to conductors or adjacent parts. There shall be no evidence of burns, abrading, or pinch marks in wire or cable insulation that could cause short circuits or leakage. The clearance between wires or cables and heat generating parts shall be sufficient to minimize deterioration of the wires or cables.

**S10. Inspection**

S10.1  *Classification of Inspections*—The inspection requirements specified herein are classified as follows:

(a) First article tests (see S10.2) and
(b) Conformance tests (see S10.3).

S10.2  *First Article Test*—First article tests shall be performed before production. First article tests shall be performed on samples that have been produced with equipment and procedures normally used in production. First article tests shall consist of the tests specified in Table S10.1. Failure of any liquid level indicating equipment to meet the requirements of this specification shall be cause for rejection.

S10.2.1  *Order of First Article Tests*—With the exception of the immersion test which may be performed at any time, the test specimens (liquid level indicating equipment) shall be subjected to the tests specified in Table S10.1 in the order listed. Any deviation in the test order shall first be approved by the buyer.

S10.3  *Conformance Tests*—Liquid level indicating equipment samples in each lot offered for delivery shall be subjected to the tests listed in Table S10.2 and shall be conducted in the order listed. Failure of any liquid level indicating equipment to meet the requirements of this specification shall be cause for rejection.

**TABLE S10.1 First Article Tests**

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**TABLE S10.2 Conformance Tests**

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S10.4  *General Examination*—Each sample equipment shall be subjected to a general examination to ascertain that the material, parts, testability, input connectors and color code, size and weight, accessibility, workmanship, design, proper cable harness dress, creepage and clearance distances, safety requirements, and treatment for prevention of corrosion are in conformance with this specification. The fit of parts shall be observed with particular reference to the interchangeability of such parts as are likely to require replacement during the normal service life of the equipment. Examination shall also check all controls, adjustments, displays, indicators, liquid level indicating equipment description, mounting devices, signal conditioner, operation, control circuit (including failsafe design), primary indicator panel assembly, auxiliary indicator
S11. Number of Test and Retests

S11.1 One liquid level indicating equipment of each type (that is, sensing technique, application, pressure range, display, and indication range) (see S4.1) shall be subjected to first article testing when specified (see S5.2).

S11.2 An inspection lot for conformance inspection shall consist of all liquid level indicating equipment of each type (that is, sensing technique, application, pressure range, display, and indication range) (see S4.1) produced under the same conditions and offered for inspection at the same time. Sampling and acceptance for Group A and Group B testing shall be as specified (see S5.2). When the number of rejected equipment, in any sample, exceeds the acceptance number for that sample, the lot represented by the sample shall be rejected.

S12. Test Methods

S12.1 Test Conditions—Except where the following factors are the variables, or unless otherwise specified in the individual test procedure, the tests specified in S12.2 shall be conducted with the liquid level indicating equipment operating under the following conditions:

(a) Ambient temperature shall be 23 ± 1.0°C.
(b) Relative humidity shall be 50 ± 5%.
(c) Supply voltage shall be 115 V ± 5%.  
(d) Supply frequency shall be 60 Hz ± 5%.  
(e) Controls shall be in the neutral or normal position.  
(f) Liquid level indicating equipment shall be mounted to simulate shipboard installation and measure the liquid level along the vertical centerline of the test tank (see S12.1.1).  
(g) Liquid level indicating equipment shall be configured to indicate liquid level height over a vertical distance equal to the normal operating range (height) of the sensing device.  
(h) The fluid/gas or fluid/water used shall be the same as the intended application (see S4.3), except that ordinary tap water having a minimum conductivity of 400 µS may be substituted for seawater interface applications. For CF applications, the fluid used for testing shall be JP-5. For CO and WO applications, the fluid used for testing shall be lube oil 2190 in accordance with MIL-L-17331, or equal. For CF/AR and CO/AR applications, the fluid used for testing shall be water having a minimum conductivity of 400 µS with a 3- ± 0.25-in. layer of JP-5 for CF/AR and lube oil 2190 in accordance with MIL-L-17331, or equal, for CO/AR applications.  
(i) The fluid temperature shall be 25 ± 10°C.

S12.1.1 Test Tank—The test tank shall be a carbon steel test tank coated for surface ship seawater tanks. The test tank shall be large enough to exercise the liquid level indicating equipment through the normal operating range (height) of the sensing device for tests specified herein. The tank shall have a sight glass or similar device with sufficient resolution and accuracy to determine the accuracy, repeatability, hysteresis, and dead band requirements of S8.3.

S12.2 Tests—The liquid level indicating equipment and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S12.2.1 Reference Measurement—When specified in the individual test, a reference measurement shall consist of measurements of the indicated level versus actual tank level. (When volumetric accuracy is required (see S5.2), the actual tank levels and the indicated levels shall be converted to volumetric levels using the capacity curve supplied by the contracting activity.) The measurements shall be measured at a minimum of ten equal increments, ± ½ % of full scale, for both increasing (upscale) and decreasing (downscale) level. The liquid level shall be maintained at each checkpoint for a time sufficient to obtain a stable measurement, but not longer than 30 s. Reference measurement accuracy shall meet the requirements of S8.3. For fluid/water interface liquid level indicating equipment, the following conditions shall apply:

(a) The tank shall be filled over the entire normal operating range (height) of the sensing device. The tank shall be full of water, full of the measured fluid, or full of some combination of water and the measured fluid.

(b) The liquid level indicating equipment shall indicate 0 % of the sensing device normal operating range (height) when the tank is full of water.

(c) The liquid level indicating equipment shall indicate 100 % of the sensing device normal operating range (height) when the tank is full of the measured fluid.

(d) The two fluids shall not be agitated in any way to create an emulsion. The two fluids shall be allowed to separate and form a distinct interface before any measurements are taken.

S12.2.2 Accuracy

S12.2.2.1 Liquid Level Indicating Equipment Operation and Accuracy—The sensing device shall be conditioned first by raising and lowering the level between 0 and 100 % of the sensing device normal operating range (height) for three consecutive cycles. Three reference measurements (see S12.2.1) shall then be made in succession. Accuracy shall be in accordance with S8.3.

S12.2.2.2 Control Circuit Accuracy—The detection points for the high control circuit setpoints shall be tested at 50, 75, and 98 % of the sensing device normal operating range (height). The detection points for the low control circuit setpoints shall be tested at 2, 25, and 50 % of the sensing device normal operating range (height). The liquid level shall be raised above then lowered below each detection point three successive times. The control circuit accuracy shall be in accordance with S8.3 at each control circuit setpoint tested.

S12.2.3 Response Time Tests—The test tank (see S12.1.1) shall be used to subject the sensing device to changes in liquid level at a constant rate. Where it is impractical to achieve the fill/empty rate specified, this test may be performed by simulating the change in fluid level (for example, raising or lowering the sensing device by means of a pneumatic cylinder) at the same rate specified.

S12.2.3.1 Indication Response Time Test—This test is applicable to all liquid level indicating equipment. When an adjustable response time is provided, the liquid level indicating equipment shall be adjusted to its minimum response time setting. The actual fluid level and the level indicated by the liquid level displays shall be monitored. The test point levels shall be 20, 50, and 80 % of the liquid level indicating
equipment normal operating range (height). The fluid level shall be increased at a constant rate of $1 \pm 0.01$ in./s through the test points and then decreased at the same rate through the test points. The elapsed time from when the actual fluid level reaches a test point level to when the liquid level indication equipment indicates the test point level, within the specified accuracy requirements (see S8.3), shall be measured both upscale and downscale. The maximum elapsed time shall be the indication response time. Performance shall conform to the requirements of S8.4.1.

S12.2.3.2 Control Circuit Response Time Test—This test is applicable only to liquid level indicating equipment with control circuit(s). When two high control circuits are provided, one setpoint shall be set at 50 % and one at 80 % of the liquid level indicating equipment normal operating range (height). When two low control circuits are provided, one setpoint shall be set at 20 % and one at 50 % of the liquid level indicating equipment normal operating range (height). When one high and one low control circuit is provided, their setpoints shall be set at 80 and 20 % of the liquid level indicating equipment normal operating range (height), respectively.

S12.2.3.2.1 Minimum Control Circuit Response Time Test—The control circuit shall be adjusted to its minimum response time setting. The fluid level shall be increased at a constant rate of $1 \pm 0.01$ in./s through the test points and then decreased at the same rate through the test points. The elapsed time from when the actual fluid level reaches a test point level to when the control circuit activates or deactivates the switching device associated with that setpoint level shall be measured both upscale and downscale. The maximum elapsed time shall be the minimum control circuit response time. Performance shall conform to the requirements of S8.4.2. This test may be done concurrently with S12.2.3.1.

S12.2.3.2.2 Maximum Control Circuit Response Time Test—The control circuit shall be adjusted to its maximum response time setting. The fluid level shall be increased at a constant rate of $0.25 + 0.005$ in./s through the test points and then decreased at the same rate through the test points. The elapsed time from when the actual fluid level reaches a test point level to when the control circuit activates or deactivates the switching device associated with that setpoint level and the elapsed time from when the actual fluid level reaches a test point level to when the liquid level indication equipment indicates the test point level within the specified accuracy requirements (see S8.4.2) shall be measured both upscale and downscale. The maximum elapsed time between when the actual fluid level reaches a test point level to when the control circuit activates or deactivates the switching device associated with that setpoint level shall be the maximum control circuit response time. The maximum elapsed time between when the actual fluid level reaches a test point level to when the liquid level indication equipment indicates the test point level within the specified accuracy requirements (see S8.4.2) shall be the indication response time. Performance shall conform to the requirements of S8.4.2.

S12.2.4 Insulation Resistance Test—The insulation resistance of the liquid level indicating equipment shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance meets the specified limit (S8.5) and is steady or increasing, the test may be terminated before the end of the 2-min period. The accuracy test (see S12.2.2) shall be performed after completion of the insulation resistance measurements. Performance shall conform to the requirements of S8.5.

S12.2.5 Specific Gravity Test

S12.2.5.1 Fluid/Gas Interface Test—This test applies only to fluid/gas interface applications in which the fluid is FO, CO, WO, CF, or JP. Two accuracy tests (see S12.2.2) shall be performed, one using water as the test fluid and the other using an organic fluid with a specific gravity of 0.86 ± 0.02, such as lube oil. The liquid level indicating equipment shall not be altered, modified, or manually adjusted during each accuracy test or between the two accuracy tests. Performance shall conform to the requirements of S8.6.

S12.2.5.2 Fluid/Water Interface Test—This test applies only to fluid/water interface applications in which the fluid is FO, CO, WO, CF, or JP. Two accuracy tests (see S12.2.2) shall be performed, the first using water and an organic fluid with a specific gravity of 0.86 ± 0.02, such as lube oil as the test fluids, and the second using water and another fluid with a specific gravity of 0.78 ± 0.02, such as kerosene, as the test fluids. The liquid level indicating equipment shall not be altered, modified, or manually adjusted during each accuracy test or between the two accuracy tests. Performance shall conform to the requirements of S8.6.

S12.2.6 Fluid Conductivity Test—This test applies only to SW, FW, WW, CO, CF, and WO applications. Three accuracy tests (see S12.2.2) shall be performed using water with a different electrical conductivity for each test. The three test conductivities of water shall be 3 ± 2, 500 ± 50, and 10 000 ± 50 µS/cm. The conductivity of the water shall be controlled by varying the concentration of sodium chloride in solution with the water. The liquid level indicating equipment shall not be altered, modified, or manually adjusted during each accuracy test or between the accuracy tests. Performance shall conform to the requirements of S8.7.

S12.2.7 Tank Wall Proximity Test—The sensing device shall be located at a corner of the test tank that is formed by two continuous steel walls and shall be equidistant from each of the two adjoining walls. The distance to each wall shall either provide 1 in. of clearance between the sensing device and the wall or shall be the minimum distance specified by the manufacturer up to a maximum of 4 in. An accuracy test (see S12.2.2) shall be performed. Performance shall conform to the requirements of S8.8.

S12.2.8 Inclination—The accuracy test (see S12.2.2) shall be performed except that the liquid level indicating equipment and the test tank shall be inclined 45°, unless otherwise specified (see S5.2), to each side of vertical along both the fore-and-aft and athwartship axes of the tank, for a total of four positions. Reference measurements (see S12.2.1) shall be taken in each of the four inclined positions. The actual liquid level
shall be measured at the inclined vertical tank centerline. Performance shall conform to the requirements of S8.9.

S12.2.9 Spike Voltage Test—The liquid level indicating equipment shall be subjected to an input supply line voltage spike of 2500-V positive peak amplitude; the voltage waveform shall be in accordance with MIL-STD-1399, Section 300, Fig. 2. Voltage Spike Impulse Wave Shape. This spike shall be impressed at normal supply line voltage and frequency while the liquid level indicating equipment is operating. The accuracy test (see S12.2.2) shall be performed at the conclusion of the test. Performance shall conform to the requirements of S8.10.

S12.2.10 Accelerated Life Test—Liquid level indicating equipment shall be subjected to the accelerated life test as specified herein. Throughout the test, the temperature of the fluid in the test tank shall be within plus or minus 5°C of the required test chamber temperature. The liquid level in the tank shall be continuously cycled from empty to full throughout the test. If the test tank is sealed from the ambient environment, the humidity inside the test tank need not meet the test chamber humidity requirements. Performance shall conform to the requirements of S8.11.

S12.2.10.1 Initial Test Conditions—The test shall begin with the following initial conditions:
(a) Equipment set up in a temperature-controlled chamber at 25 ± 5°C and relative humidity of 90 to 100 %.
(b) Equipment energized.
1—Nominal line voltage of 115 V ± 5 % and nominal frequency of 60 Hz ± 5 %.
2—Fully operational for 2 h.
(c) When equipment internal temperature has stabilized, performance parameters shall be measured as reference test data for comparison with subsequent tests.

S12.2.10.2 Temperature Conditions—After initial test conditions have been satisfied, temperature testing shall be performed as follows:
(a) Reduce chamber temperature, at a uniform rate in not less than 4 h, to the lowest operating temperature of the range specified and maintain relative humidity of 90 to 100 %.
(b) Maintain chamber temperature at the lowest operating temperature of the range for 4 h.
(c) Near the end of the fourth hour, measure performance parameters specified in S8.12.
(d) Increase chamber temperature, at a uniform rate in not less than 6 h, to the highest operating temperature of the range specified and maintain humidity at 90 to 100 %.
(e) Maintain chamber temperature at the highest operating temperature of the range specified for 4 h.
(f) Near the end of the fourth hour, measure performance parameters specified in S8.12.
(g) Reduce chamber temperature, at a uniform rate in not less than 6 h, to the lowest operating temperature of the range specified and maintain humidity at 90 to 100 %.
(h) Maintain chamber temperature at the lowest operating temperature of the range specified for 2 h.

S12.2.10.3 Voltage and Frequency Cycling Conditions—After completion of the 2-h low-temperature conditioning period specified in S12.2.10.2(h), perform the following:
(a) Decrease the input voltage to the lowest limit of the equipment voltage tolerance band.
(b) Maintain chamber temperature at the lowest operating temperature and input voltage at the lowest limit for 1 h while equipment continues to operate, then measure performance parameters specified in S8.11.
(c) Return input voltage to nominal value. Decrease input frequency to the lower limit of the equipment frequency tolerance band.
(d) Maintain chamber temperature at the lowest operating temperature and input frequency at the lowest limit for 1 h while equipment continues to operate, then measure performance parameters specified in S8.11.
(e) Return input frequency to nominal value.
(f) Increase temperature to 25 ± 5°C and maintain relative humidity at 90 to 100 %. Maintain this condition for 2 h.
(g) With equipment operating at 25 ± 5°C and relative humidity at 90 to 100 %, decrease input voltage and frequency to the lower limits of the equipment voltage and frequency tolerance bands. Maintain this condition for 1 h and then measure performance parameters specified in S8.11.
(h) Repeat S12.2.10.3(g) with input voltage at the upper limit of the equipment voltage tolerance band and input frequency at the lower limit of the equipment frequency tolerance band.
(i) Repeat S12.2.10.3(g) with input voltage and frequency at the upper limits of the equipment voltage and frequency tolerance bands.
(j) Repeat S12.2.10.3(g) with input voltage at the lower limit of the equipment voltage tolerance band and input frequency at the upper limit of the equipment frequency tolerance band.
(k) Repeat uniform temperature rise test of S12.2.10.2(d).
(l) Measure performance parameters specified in S8.12 at the end of the uniform temperature rise test of S12.2.10.3(k).
(m) With equipment operating at the highest operating temperature of the range specified and relative humidity at 90 to 100 %, increase input voltage to the upper limit of the equipment voltage tolerance band, maintaining input frequency at the upper limit of the equipment frequency tolerance band.
(n) Operate for 4 h at this condition and measure performance parameters specified in S8.11.
(o) Maintain input frequency at the upper limit of the equipment frequency tolerance band but decrease input voltage to the lower limit of the equipment voltage tolerance band.
(p) Operate for 1 h at this condition and measure performance parameters specified in S8.11.
(q) Maintain high temperature and humidity conditions but return input voltage and frequency to nominal values.
(r) Operate for 1 h at this condition and measure performance parameters specified in S8.11.
(s) Reduce temperature to 25 ± 5°C and maintain relative humidity at 90 to 100 %. Maintain this condition for 2 h.
(t) Repeat temperature, voltage, and frequency cycling tests of S12.2.10.3(g) through (s) with relative humidity at 90 to 100 % for not less than eight cycles.
(u) Repeat uniform temperature rise test of S12.2.10.2(d).
(v) Repeat temperature, voltage, and frequency cycling tests of S12.2.10.3(m) through (r) with relative humidity at 10 to 20 % for not less than ten cycles.
(w) Reduce chamber temperature, at a uniform rate in not less than 6 h, reduce relative humidity to 45 to 55 % and return temperature, voltage, and frequency to nominal values specified in S12.2.10.1.

(x) Operate for 2 h at this condition and perform accuracy (see S12.2.2) and response time (see S12.2.3) tests.

S12.2.11 Enclosure Test—Each liquid level indicating equipment enclosure to be installed partially or totally outside the tank shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. The portable indicator assembly shall be subjected to the tests in NEMA Standard 250 for Type 6 enclosures. Performance shall conform to the requirements of S8.12.

S12.2.12 Pressure Test—The components of the liquid level indicating equipment, including flexible interconnections, subject to immersion in the measured fluid, shall be installed in a pressure vessel to simulate actual tank installation so that all parts of the components, especially connections and fittings, are submerged and remain submerged except when test conditions state otherwise. Before testing, the pressure vessel with the liquid level indicating equipment installed shall be filled and allowed to soak for 1 h at atmospheric pressure. Except for the AP pressure range (see S4.4), the rate of pressure change shall not be less than 10 lb/in.²·s. For the AP pressure range, the rate of pressure change shall not be less than 5 lb/in.²·s.

S12.2.12.1 Pressure Test Procedure—The pressure test shall consist of three successive fill and empty cycles. The pressure vessel shall be filled in ten equal increments through the sensing device normal operating range (height) at atmospheric pressure and level readings taken at each increment. The specified pressure (see below) shall then be applied and held for 1 h. While maintaining the specified pressure with compressed gas, the pressure vessel shall be emptied in ten equal increments and level readings shall be taken at each increment. The pressure shall then be reduced to atmospheric for 10 min and the cycle repeated twice. During the third pressure cycle, an insulation resistance measurement (see S12.2.4) shall be made on the sensing device at both the specified pressure and at atmospheric pressure. The specified pressure for the test shall be as follows:

(a) AP pressure range sensing devices shall be subjected to 30 psig.
(b) VP and LP pressure range sensing devices shall be subjected to 150 psig.
(c) HP pressure range sensing devices shall be subjected to 150 % of the maximum pressure specified (see S5.2).

S12.2.12.2 Posttest Inspection—Upon completion, the sensing device shall then be removed from the pressure vessel and disassembled to the maximum extent possible without affecting sensing device performance or integrity. The sensing device shall be examined for any physical or electrical damage and leakage or signs of leakage. The sensing device shall then be reassembled and a reference measurement (see S12.2.1) taken. Performance shall conform to the requirements of S8.13.

S12.2.13 Vibration Test—Liquid level indicating equipment shall be tested in accordance with Type I (environmental) vibration of MIL-STD-167-1. Components of the liquid level indicating equipment, including sensing devices, shall be mounted to simulate shipboard installations in an empty tank and shall not be restricted from normal operation and movement. The equipment under test shall be energized in the normal manner. At the conclusion of the test and before any adjustments, accuracy shall be measured (see S12.2.2). Liquid level indicating equipment shall be physically examined for evidence of mechanical or electrical damage or loosening of parts. Performance shall conform to the requirements of S8.14.

S12.2.14 Shock Test—Liquid level indicating equipment shall be tested in accordance with Grade A, Class 1, Type A equipment as specified in MIL-STD-624. The liquid level indicating equipment shall be energized in the normal manner. Components of the liquid level indicating equipment, including sensing devices, shall be mounted to simulate shipboard installation in an empty tank and shall not be restricted from normal operation and movement. If individual components of the liquid level indicating equipment must be shock tested separately because of size or weight, the complete liquid level indicating equipment shall be connected together (electrically and mechanically) as designed, energized, and the output and control circuit signals monitored during the test. At the conclusion of the test and before any adjustments, the accuracy shall be measured as specified in S12.2.2. The liquid level indicating equipment shall be physically examined for evidence of mechanical or electrical damage or loosening of parts. Performance shall conform to the requirements of S8.15.

S12.2.15 DC Magnetic Field—The liquid level indicating equipment shall be tested in accordance with MIL-STD-1399, Section 070, Part 1. Unless otherwise specified (see S5.2), the magnetic field strength shall be 400 A/m. Performance shall conform to the requirements of S8.16.

S12.2.16 Electromagnetic Interference Tests—EMI tests shall be in accordance with the test methods specified in MIL-STD-461, with the modifications as specified in S8.17. Upon completion of the EMI tests, an accuracy test (see S12.2.2) shall be performed. Performance shall conform with the requirements of S8.17.

S12.2.17 Flexible Interconnection Immersion Test—When intended for use in tanks containing CF, CO, WO, FO, or JP type fuels, flexible interconnections shall be submerged in JP5 for a continuous period of 45 days. The test fluid temperature shall be maintained at 25 ± 10°C. Removable flexible interconnections may be tested with a simulated shipboard installation using test fixtures to replace sensing devices. After completion of immersion testing, the flexible interconnection shall undergo a physical examination and insulation resistance test (see S12.2.4). Performance shall conform to the requirements of S8.18.

S12.2.18 Supply Line Voltage and Frequency Variation—Liquid level indicating equipment shall be operated at normal, maximum, and minimum steady state voltages and frequencies (see S8.11.1). The liquid level indicating equipment shall remain at each configuration for 15 min. A reference measurement (see S12.2.1) shall be performed before and after each transition. Performance shall conform to the requirements of S8.11.1.
S13. Certification

S13.1 The purchase order or contract should specify whether the buyer shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer’s facility for review by buyer upon request.

S14. Product Marking

S14.1 Marking—Unless otherwise specified (see S5.2), all major liquid level indicating equipment components shall be marked or provided with label plates. Markings on plastic or metallic materials shall be made by stamping, engraving, stenciling, or rubber-stamping with smudgeproof ink covered with a coat of clear lacquer or silk screening. Label plates shall be made with engraved or stamped markings. At a minimum, labels and markings shall contain:

(a) “LIQUID LEVEL INDICATOR,”
(b) Component name,
(c) Manufacturer’s name,
(d) National Stock Number (NSN), if available,
(e) Date of manufacture, and
(f) Designation (see S4.1).

A label plate marked with manufacturer’s part number and serial number shall be permanently affixed on the front of each indicator panel assembly.

S15. Packaging and Package Marking

S15.1 Packaging and package marking shall be in accordance with Section 15.

S16. Quality Assurance

S16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see S5.2).

S16.2 Warranty—Any special warranty requirements shall be specified in the acquisition requirements (see S5.2).
1. Scope

1.1 This specification covers the requirements for direct and indirect reading sight liquid level indicators for general applications. General applications for indirect reading sight glasses are water and fuel service at working pressures 2.07 MPa (300 lb/in.2) and below, temperatures of 149°C (300°F) and below. General applications for direct reading sight glasses are applications in which the temperature does not exceed 66°C (150°F).

1.2 Direct reading sight glass indicators may consist of glass or plastic tubes with fittings including shutoff valves. Glass tubes may be used for low shock direct reading sight glass indicators in which the fluid is not compatible with plastic.

1.3 Indirect reading indicators may consist of a sealed chamber with a magnetic float or flag indicator.

1.4 Special requirements for naval shipboard applications are included in the supplement to this standard.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
D 3951 Practice for Commercial Packaging

2.2 ANSI Standards:
B16.5 Pipe Flanges and Flanged Fittings (DoD adopted)

3. Terminology

3.1 Definitions:
3.1.1 SI (Le Systeme International d’Unites) Units—units of measurement recognized by the CIPM (Comite International des Poids et Mesures).

4. Design Classification

4.1 Types—Indicator designs are classified as either direct reading or indirect reading. Both types are depicted in Fig. 1, complete with dimensions that facilitate ordering.

4.2 Special Considerations—Special considerations that may affect selection and installation are listed below. This is not to be construed as a complete listing.

(a) Type of indicator,
(b) Manual or automatic shutoff valves,
(c) Indication length of liquid level range,
(d) Method of connection,
(e) Location of indicator relative to vibrating equipment,
(f) Protection of the instrumentation,
(g) Application of each indicator,
(h) Cleaning procedure or reference to the cleaning procedure being used, and
(i) Selection of indicator for compatibility with materials, temperature, pressure, ambient environment, and with the parameter being measured.

5. Ordering Information

5.1 The buyer shall provide the manufacturer with all of the pertinent application data outlined in the acquisition requirements.

5.2 Acquisition Requirements—Acquisition documents shall specify the following:

(a) Title, number, and date of this specification;
(b) Type and quantity of indicators required;
(c) Manufacturer’s part number;
(d) When qualification testing is required;
(e) Final disposition of qualification test samples;
(f) Environmental requirements;
(g) Operating media;
(h) Viscosity and specific gravity of fluid for indirect indicators;
(i) Materials;
(j) Indication length;
(k) Size and type of connections;
(l) Shutoff valve requirements;
(m) Cleaning requirements;
(n) When certification is required;
(o) Marking requirements;
(p) Unique packaging requirements; and
(q) Unique preservation requirements.

6. Materials and Manufacture

6.1 Materials—The materials for all wetted parts shall be selected for long-term compatibility with the process medium and ambient conditions.

6.2 Material Inspection—The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with the specifications and standards as applicable.

6.3 Gaskets and O-Rings—Gaskets and O-rings shall be fabricated of materials suitable to the operating pressure, temperature, and process medium for each application.

7. Physical Properties

7.1 Connections—Sight indicators are usually installed using standard pipe fittings or flanges. Pipe fittings and material should match that of the existing pipe for each installation. Type and size of fittings shall be specified in the acquisition requirements. Welding or brazing shall be performed in accordance with industry standards.

7.2 Flanged Connections—Where sight indicators are installed using flanges, flanges shall be in accordance with ANSI B16.5. Standard flange sizes include 1.27 cm (½ in.), 1.9 cm (¾ in.), 2.54 cm (1 in.), 3.8 cm (1-½ in.), and 5.08 cm (2 in.). Standard flange pressure ratings include 1.034 MPa (150 psi), 2.07 MPa (300 psi), and 4.14 MPa (600 psi). Other flange requirements shall be specified in the acquisition requirements.

7.3 Vent and Drain Connections—Where required, vent and drain connections are usually plugged, ½- or ¾-in. NPT or

FIG. 1 Indicator Design Types
with NPT valves. Other vent and drain connections shall be specified in the acquisition requirements.

8. Performance Requirements

8.1 Performance Considerations—In many applications, certain performance characteristics are deemed critical to the intended or desired function of a sight liquid level indicator. The following are prime examples:
   (a) Accuracy,
   (b) Shock and vibration classifications, and
   (c) Operating pressure and temperature ranges.

9. Workmanship, Finish, and Appearance

9.1 Finish and Appearance—Any special surface finish and appearance requirements shall be specified in the acquisition requirements.

9.2 Sight Glass Cleaning—Any special cleaning requirements shall be specified in the acquisition requirements.

10. Inspection

10.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:
   (a) Qualification testing and
   (b) Quality conformance testing.

10.2 Qualification Testing—Qualification test requirements shall be specified where applicable. Qualification test methods should be identified for each design and performance characteristic specified. Test report documentation requirements should also be specified.

10.3 Quality Conformance Testing—Quality conformance testing is accomplished when qualification testing was satisfied by a previous acquisition or product has demonstrated reliability in similar applications. Quality conformance testing is usually less intensive than qualification, often verifying that samples of a production lot meet a few critical performance requirements.

11. Number of Tests and Retests

11.1 Test Specimen—The number of test specimens to be subjected to qualification testing shall depend on the design. If each range is covered by a separate and distinct design, a test specimen for each range will require testing. In instances in which a singular design series may cover multiple ranges and types, only three test specimens need be tested provided the physical similarities are approved by the buyer. In no case, however, shall less than three units, one unit each representing low, medium, and high ranges, be tested, regardless of design similarity.

12. Test Methods

12.1 Tests—All tests shall be performed in accordance with ASTM, ASME, or industry standards as specified.

12.2 Test Data—All test data shall remain on file at the manufacturer’s facility for review by the buyer upon request. It is recommended that test data be retained in the manufacturer’s files for at least three years or a period of time acceptable to the buyer and manufacturer.


13.1 Warranty—Unless otherwise specified, the manufacturer is responsible for the following:
   (a) All materials used to produce a unit and
   (b) Manufacturer will warrant his product to be free from defect of workmanship to produce the unit.

14. Certification

14.1 When specified in the purchase order or contract, the buyer shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

15. Product Marking

15.1 User-specified product marking shall be listed in the acquisition requirements.

16. Packaging and Package Marking

16.1 Packaging of Product for Delivery—Product shall be packaged for shipment in accordance with Practice D 3951.

16.2 Any special preservation, packaging, or package marking requirements for shipment or storage shall be identified in the acquisition requirements.

17. Keywords

17.1 direct level indicator; indirect level indicator; liquid level indicator; sight glass
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard (Specification F 2045) and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supersedes MIL-I-20037, Indicators, Sight, Liquid Level, Direct/Indirect Reading, Tubular Glass/Plastic, for new ship construction.

INDICATORS, SIGHT, LIQUID LEVEL, DIRECT AND INDIRECT READING, TUBULAR GLASS/PLASTIC (NAVAL SHIPBOARD USE)

S1. Scope

S1.1 This supplement covers sight liquid level indicators of the direct and indirect reading type having tubular glass, clear polycarbonate, or rigid polyvinyl chloride (PVC).

S1.2 Direct reading sight glass indicators may consist of glass or plastic tubes with fittings including shutoff valves. Indirect reading indicators may consist of a sealed chamber with a magnetic float or flag indicator.

S1.3 Indirect indicators are intended for use in water and fuel service at working pressures of 2.07 MPa (300 lb/in.²) and below, temperatures of 149°C (300°F) and below, and for hi-shock applications. Direct indicators are intended for use in hi-shock applications and shall use plastic sight tubes where the fluid is compatible and temperatures do not exceed 66°C (150°F). Glass tubes shall only be used for low shock applications and where the fluid is not compatible with plastic tubes.

S1.4 Only direct-type indicators with glass tube material less than 92 cm (36 in.) in length or indirect type indicators shall be used for hydrocarbons and flammable fluid applications.

S2. Referenced Documents

S2.1 Commercial Documents:
- ANSI B16.5 Pipe Flanges and Flanged Fittings (DoD adopted)⁴
- ASTM A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes (DoD adopted)⁵
- ASTM B 61 Specification for Steam or Valve Bronze Castings (DoD adopted)⁶
- ASTM B 62 Specification for Composition Bronze or Ounce Metal Castings (DoD adopted)⁶
- ASTM B 117 Practice for Operating Salt Spray (Fog) Apparatus⁷
- ASTM B 283 Specification for Copper and Copper-Alloy Die Forging Hot-Pressed⁸
- ASTM D 1784 Specification for Rigid Poly Vinyl Chloride PVC Compounds and Chlorinated Poly Vinyl Chloride CPVC Compounds (DoD adopted)⁸
- ASTM D 3935 Specification for Polycarbonate (PC) Unfilled and Reinforced Material⁹
- ASTM D 3951 Practice for Commercial Packaging¹⁰
- MSS-SP-72 Ball Valves with Flanged or Butt-Welding Ends for General Service¹¹
- MSS-SP-110 Ball Valves, Threaded Socket-Welding, Solder Joint, Grooved and Flared Ends¹¹

S2.2 Government Documents:
- Military Standards: MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)¹²
- Military Specifications: MIL-S-901 Shock Tests, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for¹²
- Other Government Documents: Drawings and publications, Naval Sea Systems Command (NAVSEA)
  - 803-5184222 Gage Glass Ball Valve¹²
  - S8700-1385802 Level Indicator Shield¹²
  - S9074-AR-GIB-010/278 Requirements for Fabrication Welding and Inspection and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels¹²

S3. Terminology

S3.1 Definitions:

S3.1.1 direct indication—the tank fluid level is visible in the glass or tube.

S3.1.2 indirect indication—the tank fluid level is contained in a sealed chamber and indicated by some other means such as a float or flag actuated by a magnet contained in a float in the fluid chamber.

⁴ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
⁵ Available from Annual Book of ASTM Standards, Vol 01.01.
⁶ Available from Annual Book of ASTM Standards, Vol 02.01.
⁷ Available from Annual Book of ASTM Standards, Vol 03.02.
⁸ Available from Annual Book of ASTM Standards, Vol 08.01.
⁹ Available from Annual Book of ASTM Standards, Vol 08.02.
¹¹ Available from Manufacturers’ Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.
¹² Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.
S4. Design Classification

S4.1 Designation—Sight glass indicator designation shall consist of a series of designations which shall be assigned and listed in the format below:

Example: F 2045-SGI-D-A-PLY-PA

<table>
<thead>
<tr>
<th>Specification</th>
<th>Equipment Designator</th>
<th>Indication</th>
<th>Shutoff Valve</th>
<th>Sight Glass Tube</th>
<th>Application Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>F 2045</td>
<td>(see S4.2)</td>
<td>(see S4.3)</td>
<td>(see S4.4)</td>
<td>(see S4.5)</td>
<td>(see S4.6)</td>
</tr>
</tbody>
</table>

S4.2 Equipment Designator—The level indicator shall be designated as SGI—Sight Glass Indicator.

S4.3 Indication—The type of indication desired shall be specified as follows:

D—Direct indication
I—Indirect indication

S4.4 Shutoff Valves—The sight glass indicators shall be equipped with a manual or automatic shutoff valve of the ball-check type depending on the type of indication specified. Valve type shall be designated as:

A—Automatic for direct indication
M—Manual for indirect indication

S4.5 Sight Glass Material—The tube material of direct reading sight glass indicators shall be designated as follows:

GWT—Glass with teflon heat shrink tube
PLY—Polycarbonate
PVC—Rigid polyvinyl chloride

S4.6 Application—The sight glass indicators may be used, but are not limited to, the following applications:

LA—Lubricating oil and air interface
PA—Potable water and air interface
DA—Diesel oil and air interface
JA—JP fuel and air interface
FT—Deaerating feed tanks
FA—Feed water and air interface
AG—Aviation gasoline
3F—Aqueous film-forming fluid

S5. Ordering Information

S5.1 The buyer shall provide the manufacturer with all of the pertinent application data shown in accordance with S5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S5.2 Acquisition Requirements—Acquisition documents shall specify the following:

(a) Title, number, and date of this specification;
(b) Quantity and designation of indicator;
(c) Size of connection if specified;
(d) Handwheel with chain when required;
(e) Dimensions, as applicable (see Fig. 1);
(f) Operating temperature, minimum and maximum;
(g) Operating pressure, normal and maximum;
(h) Operating media;
(i) Viscosity and specific gravity of fluid for indirect indicators only;
(j) When qualification testing is required;
(k) Final disposition of qualification test samples;
(l) National Stock Number (NSN) if available;
(m) Unique product marking requirements; and
(n) Unique packaging requirements.

S6. Materials and Manufacture

Piping material used in the construction of sight glass indicators shall be compatible with the intended service piping and media. Material for indirect indicators using a magnetic operating principle shall be corrosion-resistant steel in accordance with Type 304 of Specification A 312. Only direct-type indicators with glass tube material less than 91.44 cm (36 in.) in length or indirect-type indicators shall be used for hydrocarbon and flammable fluid applications.

S6.1 Castings—The composition of castings shall be in accordance with Specifications B 61 or B 62.

S6.2 Forgings—The composition of forgings shall be in accordance with Alloy 632M of Specification B 283.

S6.3 Welding—Welding and nondestructive testing shall be in accordance with NAVSEA Publication S9074-AR-GIB-010/278. In no case shall such processes as peening or plugging be used on castings or forgings for reclaiming any parts.

S6.4 Glass—Glass tubing shall be of annealed borosilicate transparent glass with a 1.59-cm (5/8-in.) outside diameter (o.d.) and a minimum wall thickness of 0.24 cm (3/32 in.) with a transparent fluorinated ethylene propylene plastic insulating sleeving heat shrunk over the glass tube. Glass tubes shall be used for temperatures above 66°C (150°F) but not to exceed 132°C (270°F) or where the fluid is not compatible with polycarbonate or rigid PVC. Maximum length of glass tubes shall be as specified in Drawing 803-5184222.

S6.5 Plastics—Plastics used in the sight glass indicator shall be polycarbonate in accordance with Specification D 3935 or rigid PVC in accordance with Specification D 1784.

S6.6 Recovered Materials—Unless otherwise specified herein, all equipment, material, and articles incorporated in the products covered by this specification shall be new and shall be fabricated using materials produced from recovered materials to the maximum extent practicable without jeopardizing intended use. The term “recovered materials” means materials that have been collected or recovered from solid waste and reprocessed to become a source of raw materials as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or rebuilt products is allowed under this specification unless specified.

S7. Physical Properties

S7.1 Design and Construction—The indicators shall be constructed so as to allow replacement of the glass tube or indicating element and also allow cleaning from either end without loosening any packing or sealing material while the pressure vessel is under pressure.

S7.1.1 Sizes—Unless otherwise specified in the acquisition requirements, the connections of direct indicators shall be of the size specified for the diameter of the tube in accordance with Table S7.1.

<table>
<thead>
<tr>
<th>TABLE S7.1 Connection Sizes</th>
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</thead>
<tbody>
<tr>
<td>Tube Diameter</td>
</tr>
<tr>
<td>1.59 cm (%-in. o.d.)</td>
</tr>
<tr>
<td>1.91 cm (%-in. o.d.)</td>
</tr>
</tbody>
</table>

S7.1.2 Valves:
S7.1.2.1 Nonautomatic Shutoff—The nonautomatic shutoff valve shall be in accordance with MSS SP-72 or MSS SP-110.

S7.1.2.2 Automatic Shutoff—Direct indicators shall have an automatic shutoff valve of the solid ball-check type in accordance with Drawing 803-5184222. The check valve shall be constructed so as to allow leakage of 5 to 25 cm³ per minute at 345 kPa (50 lb/in.²) when the check valve is in the closed position.

S7.1.2.3 Handwheel—When required for remote operation, the shutoff valves shall be furnished with a handwheel having an o.d. not less than 8.89 cm (3 ½ in.) and with holes drilled in the rim located for adapting to chain operation. When specified in the acquisition requirements, chain shall be provided.

S7.1.2.4 Glands—Glands for direct reading gage glasses shall be designed to minimize torsional stress on the glass when the gland is tightened.

S7.2 Protection:

S7.2.1 Class A—The glass tube of direct indicators shall be protected from damage by not less than four solid rods of corrosion-resistant material a minimum of 0.64 cm (1/4 in.) in diameter of sufficient length to allow for a maximum 91.44-cm (36-in.) tube length. A shield shall be provided in accordance with Drawing S8700-1385802 for combustible fluids.

S7.2.2 Class B—Where all plastic sight tubes are used, protective rods or shields are not required. Protective rods or shields shall not be required for indirect indicators.

S7.3 Connections—Sight glass indicators shall have flat-faced ranged connections. Flanges shall be 1.91 cm (¾ in.) in accordance with the dimensions of ANSI B16.5 classes. The flange rating shall be compatible with the maximum pressure and temperature conditions expected in the intended application and shall be based upon the ratio of the allowable stress at temperature of the material used to that for the material specified in ANSI B16.5.

S7.3.1 Drain Connections—The indicators shall have a drain connection to which a drain line may be connected. For pressures below 345 kPa (50 lb/in.²), the drain line connection shall be ¾-in. NPT or larger. For pressures of 345 kPa (50 lb/in.²) or above, the drain line connection shall be a welded socket pipe nipple, ½-in. NPS or larger.

S7.4 Temperature—Direct reading indicators using plastic tubes shall not be used in applications above 66°C (150°F). Glass tubes shall be used for temperatures above 66°C (150°F) but not to exceed 132°C (270°F). Indirect reading indicators using flags in the indicator may be used up to 149°C (300°F) with plastic flags and 232°C (450°F) with aluminum flags.

S7.5 Working Pressure:

S7.5.1 Direct Indicators—Maximum working pressure for direct indicators shall be as specified on Drawing 803-5184222.

S7.5.2 Indirect Indicators—Maximum working pressure for indirect indicators shall be 2.07 MPa (300 lb/in.²) at 149°C (300°F).

S7.6 Interchangeability—Parts, components, and attachments shall be interchangeable with parts and components of the same types and classes produced by the same contractor.

S8. Performance

S8.1 Accuracy:  

S8.1.1 Direct Indicator Accuracy—Accuracy of direct indicator shall be within ±1.27 cm (½ in.).  

S8.1.2 Indirect Indicator Accuracy—Accuracy of the indirect indicator shall be within ±2.54 cm (1 in.). In addition, when indirect indicators are capable of providing a remote indication, the remote indication shall be accurate to within ±3% of full scale.

S8.2 Hydrostatic Effects—Each indirect sight glass indicator shall be capable of withstanding a hydrostatic pressure of 3.1 MPa (450 lb/in.²) when tested in accordance with S12.2.2.1. Each direct sight glass indicator shall be capable of withstanding a hydrostatic pressure of 3.1 MPa (450 lb/in.²) when tested in accordance with S12.2.2.3.

S8.3 Inclination—The indirect sight glass indicator shall provide accurate operation when inclined up to a 45° in any direction and tested as specified in S12.2.3.

S8.4 Salt Spray—The sight glass indicator shall provide accurate operation in a salt spray marine environment when tested as specified in S12.2.4.

S8.5 Reliability—The sight glass indicator shall operate reliably in a naval shipboard environment for a service life of at least 40 000 h. The sight glass indicator shall be mechanically reliable for operating at least 2000-h mean time between failures at a 90% confidence level. A failure is any malfunction that requires unscheduled corrective maintenance of more than 1 h or which requires replacement of the equipment. The reliability of the sight glass indicator shall be demonstrated in accordance with S12.2.5.

S8.6 Shock—The indicator shall show no signs of damage when exposed to Grade A, Class I shock for indirect indicators and Grade B for direct indicators in accordance with MIL-S-901 as specified in S12.2.6.

S8.7 Vibration—The indicator shall show no signs of damage when exposed to Type I vibration in accordance with MIL-STD-167-1 as specified in S12.2.7.

S9. Workmanship, Finish, and Appearance

S9.1 Cleaning and Surface Finishes—Surfaces of castings, forgings, molded parts, stampings, and machined and welded parts shall be free of defects such as cracks, porosity, undercuts, voids, and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn-through. There shall be no warpage or dimensional change as a result of heat from welding operation. There shall be no damage to adjacent parts resulting from welding.

S10. Inspection

S10.1 Inspection System—The testing set forth in this specification shall become a part of the manufacturer’s overall inspection system or quality program. The manufacturer’s quality system shall comply with the requirements of ANSI/ASQC 9001-1994, Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing. Certification and registration is highly desired but not required.

S10.2 Classification of Inspections—The inspection requirements specified herein are classified as follows:
(a) Qualification testing and
(b) Quality conformance testing.

S10.3 Qualification Testing—Qualification testing shall consist of two samples of each type indicator subjected to the examinations and tests in accordance with Table S10.1 in the order shown. Failure of any sight glass indicator to meet the requirements of this specification shall be cause for rejection.

<table>
<thead>
<tr>
<th>TABLE S10.1 Qualification and Quality Conformance Testing</th>
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<tbody>
<tr>
<td>Examination or Test</td>
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<tr>
<td>---------------------</td>
</tr>
<tr>
<td>General examination</td>
</tr>
<tr>
<td>Accuracy</td>
</tr>
<tr>
<td>Hydrostatic test</td>
</tr>
<tr>
<td>Inclination</td>
</tr>
<tr>
<td>Salt spray</td>
</tr>
<tr>
<td>Reliability</td>
</tr>
<tr>
<td>Shock</td>
</tr>
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</table>

S10.4 Quality Conformance Testing—Sight glass indicators that are produced on the same facilities, using identical materials, manufacturing, and assembly procedures shall be subjected to the quality conformance tests specified in Table S10.1. Sight glass indicators of the same type, class, and size offered for delivery at one time shall be considered a lot for purposes of inspections and tests.

S11. Number of Tests and Retests

S11.1 The number of tests and retests, if any, shall be specified in the acquisition requirements.

S12. Test Methods

S12.1 General Examination—Sight glass indicators shall be given a thorough examination to determine that it conforms to this specification and the approved drawings with respect to material, finish, construction, assembly, dimensions, workmanship, marking, identification, and information plates.

S12.2 Test Methods:

S12.2.1 Accuracy—Indicator accuracy shall be determined by mounting the indicator assembly to a test tank with a capacity at least 10 % greater than the total indication at the indicator. The tank shall be filled to the zero point of the indicator and in 10 % increments until the maximum level of the indicator is reached. Measurements of the actual fluid level of the tank shall be compared to level shown on the indicator. Indicator accuracy shall be in accordance with S8.1.

S12.2.2 Hydrostatic Tests—Sight glass indicators shall be tested at ambient conditions as a complete assembly for strength and porosity. With the shutoff valves in the open position, a pressure of 3.1 MPa (450 lb/in.²) shall be applied for 20 min. Any weeping, porosity, or deformation shall be cause for rejection. Indicators having plastic sight tubes shall have no permanent deformation of the tube upon release of the test pressure. Upon completion of the test, the pressure shall be reduced to 2.07 MPa (300 lb/in.²) and the valve shall be checked for closing readily against the maximum working pressure of the indicator. The valve shall operate with a maximum force of 13.6 kg (30 lbs).

S12.2.3 Inclination Test—Indirect indicators shall be tested inclined at 45° forward, backward, left, and right. The fluid level shall be varied between 20 to 80 % indication to verify satisfactory operation.

S12.2.4 Salt Spray—The complete indicator assembly and shutoff valves shall be subjected to a salt spray in accordance with Test Method B 117. No appreciable corrosion or other damage shall be evident after exposure to the salt spray.

S12.2.5 Reliability—Reliability of the assembled indicator shall be demonstrated by the following tests:

S12.2.5.1 Cycling—The assembled indicator and shutoff valves shall be cycled at a minimum of 25 000 cycles at the rate of 3 to 6 cycles per minute. The fluid level shall be varied between 20 to 80 % of the total indication level. Test temperature and pressure shall be in accordance with 803-5184222, Notes 17B, C, and D. During the cycling period, the following tests shall be conducted:

(a) After every 1000 cycles, the indicator shall be blown down by shutting the lower indicator shutoff valve and rapidly opening the indicator drain valve. Shut the drain valve and reopen the indicator lower shutoff valve.

(b) Thermal Shock. After every 3000 cycles, the indicator shall be allowed to cool to ambient temperature 24 ± 1°C (75 ± 2°F) and drained. The indicator shall be rapidly filled with hot water, 93 to 100°C (200 to 212°F) for glass tubes, 66°C (150°F) for rigid PVC tubes, to the maximum indication level. After 2 min, the indicator shall be drained and rapidly refilled with cold water, 10°C (50°F). Any evidence or spalling, cracking, breaking of the sight glass, or any abnormal wear or material deformation (during or at the end of the tests) shall constitute a failure.

S12.2.5.2 Hydrostatic—Upon completion of the 25 000 cycles, the indicator and valves shall be subjected to the hydrostatic test as specified in S8.2.

S12.2.6 Shock—Indicators shall be subjected to shock in accordance with MIL-S-901, Class I, Grade A for indirect indicators and Grade B for direct indicators. The indicators shall be tested as a complete assembly mounted on a Type 4-A mounting fixture. The shock test shall be performed in the following sequence:

(a) Valves open, indicator at 50 % fluid level and pressurized to normal working pressure. A total of nine blows shall be applied, three blows shall be applied parallel to each of the three principal axes.

(b) Valves shut, normal working pressure applied to valve inlet. Indicator dry and drain plug removed. A total of nine blows shall be applied, three blows shall be applied parallel to each of the three principal axes.

After exposure to shock, the indicator shall be refilled and the fluid level varied between 20 to 80 % to ensure satisfactory
operation. The shutoff valves shall be hydrostatically tested to 3.1 MPa (450 lb/in.\(^2\)) in the open position to check for body and valve stem leakage and the closed position to check for seat leakage. The indicators and valves shall be disassembled and visually examined for any damage.

S12.2.7 Vibration—The complete indicator assembly shall be subjected to vibration in accordance with MIL-STD-167-1, Type I. The indicator shall be filled to the 50% indication level and pressurized to normal working pressure during exposure to vibration. After exposure to vibration, the operation of the indicator shall be accurate when the fluid level is varied between 20 to 80% of the indicator range.


S13.1 Warranty—Special warranty requirements shall be specified in the acquisition requirements. Otherwise, the standard commercial warranty applies.

S14. Certification

S14.1 When specified in the purchase order or contract, the buyer shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test result shall be furnished. It is recommended that all test data remain on file for three years at the manufacturer’s facility for review by buyer upon request.

S15. Product Marking

S15.1 Unique product marking or identification plate requirements shall be specified in the acquisition requirements.

S16. Packaging and Package Marking

S16.1 Packaging shall be in accordance with the requirements of Practice D 3951. Unique preservation, packaging, or package marking requirements shall be specified in the acquisition requirements.

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1. Scope

1.1 This specification covers various tachometers capable of measuring rotational shaft speed.

1.2 Special requirements for tachometer types used in naval shipboard applications are included in Supplement S1.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:
D 3951 Practice for Commercial Packaging

3. Terminology

3.1 Definitions:
3.1.1 SI (Le Systeme International d’Unites) Units—units of measurement recognized by the Comite' International des Poids et Mesures (CIPM).

3.1.2 tachometer—an instrument capable of generating, transmitting, and indicating information or signal that can be converted into a function of rotational speed.

4. Classification

4.1 Design Types—The following are among the types of tachometers available:
(a) Centrifugal;
(b) Centrifugal, flexible drive;
(c) Chonometric;
(d) Electrical, alternating current (ac) voltage responsive, direct drive;
(e) Electrical reactance;
(f) Electrical, magnetovoltmeter, direct drive;
(g) Electrical, magnetovoltmeter;
(h) Frequency responsive, electrical control box and voltmeter, direct drive;
(i) Frequency sensitive, electrical, nonrotating magnetic pickup, direct drive, consists of a magnetic pickup, transducer, and indicator;
(j) Photoelectric;
(k) Digital contact;
(l) Centrifugal, flexible drive; and
(m) Vibrating resonant reed.

5. Ordering Information

5.1 The buyer shall provide the manufacturer with all of the pertinent application data in accordance with the acquisition requirements, 5.2.

5.2 Acquisition Requirements—Acquisition documents shall specify the following:
(a) Title, number, and date of this specification;
(b) Quantity of tachometers required;
(c) Range;
(d) Manufacturer’s part number;
(e) When qualification inspection is required;
(f) Final disposition of qualification test samples;
(g) Type of electrical connection;
(h) Mounting method;
(i) Environmental requirements;
(j) Materials;
(k) Size and weight restrictions;
(l) Critical service life requirements;
(m) Performance requirements;
(n) Surface finish requirements;
(o) Cleaning requirements;
(p) When certification is required;
(q) Marking requirements;
(r) Packaging requirements; and
(s) Preservation requirements.

6. Materials and Manufacture

6.1 Material Selection—The materials for all parts shall be selected for long-term compatibility with the environment in which the tachometer will be installed or used.

6.2 Material Inspection—The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with the specifications and standards as applicable.
7. Physical Properties

7.1 Size and Weight—The buyer may have intended applications where size and weight are limited. Size and weight limitations shall be specified in the acquisition requirements.

8. Performance Requirements

8.1 Service Life—The buyer may have a minimum specified service life requirement. Critical service life requirements shall be specified in the acquisition requirements.

8.2 Tachometer Performance—Performance tolerances are usually specified in percentage of range span. The following performance characteristics and environmental exposures may or may not be important to each buyer’s intended application.

(a) Accuracy,
(b) Repeatability,
(c) Damping,
(d) Temperature,
(e) Humidity,
(f) Salt spray,
(g) Vibration,
(h) Shock, and
(i) Electromagnetic interference (EMI).

9. Workmanship, Finish, and Appearance

9.1 Cleaning, Finish, and Appearance— Any special cleaning, surface finish, and appearance requirements shall be specified in the acquisition requirements.

10. Inspection

10.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

(a) Qualification testing and
(b) Quality conformance testing.

10.2 Qualification Testing—Qualification test requirements shall be specified, where applicable. Test methods should be identified for each design and performance characteristic specified. Test report documentation requirements should also be specified.

10.3 Quality Conformance Testing—Quality conformance inspection is accomplished when acceptance and qualification testing is satisfied by a previous acquisition or when the product has demonstrated reliability in similar applications. Quality conformance inspection is usually less intensive than acceptance and qualification, often verifying that samples of a production lot meet a few critical performance requirements.

11. Number of Tests and Retests

11.1 Test Specimens—The number of test specimens to be subjected to qualification testing shall depend on the tachometer design. If each range is covered by a separate and distinct design, a test specimen for each range will require testing. In instances in which a singular design series may cover multiple ranges and types, it is recommended that three test specimens be tested provided the electrical and mechanical similarities are approved by the buyer. In no case, however, should less than three units, one unit each representing low, medium, and high ranges, be tested, regardless of design similarity.

12. Test Methods

12.1 Tests—All tests shall be performed in accordance with ASTM, ASME, or industry standards as specified.

12.2 Test Data—All test data shall remain on file at the manufacturer’s facility for review by the buyer upon request. It is recommended that test data be retained in the manufacturer’s files for at least three years or a period of time acceptable to the buyer and manufacturer.


13.1 Warranty:

13.1.1 Responsibility for Warranty—Unless otherwise specified, the manufacturer is responsible for the following:

(a) All materials used to produce a unit and
(b) Manufacturer will warrant his product to be free from defect of workmanship to produce the unit.

14. Certification

14.1 When specified in the purchase order or contract, the buyer shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification, and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

15. Product Marking

15.1 User-specified product marking shall be listed in the acquisition requirements. The minimum data to be clearly marked on each tachometer shall include the following:

(a) Manufacturer’s name,
(b) Manufacturer’s part number,
(c) Serial number or lot number,
(d) Date of manufacture, and
(e) Range.

16. Packaging and Package Marking

16.1 Packaging of Product for Delivery—Product shall be packaged for shipment in accordance with Practice D 3951.

16.2 Any special preservation, packaging, or package marking requirements for shipment or storage shall be identified in the acquisition requirements.

17. Keywords

17.1 tachometer
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard (Specification F 2046) and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supersedes MIL-T-16049C, Tachometers: Electrical; Self-Generating; Mechanical, Fixed Mounting, and Hand Held; and Vibrating Reed, for new ship construction. This document also supersedes MIL-T-24797, Tachometers, Fiber Optic, (Naval Shipboard Use), (Metric) General Specification for, for new ship construction.

TACHOMETERS: ELECTRIC AND FIBER OPTIC, FIXED MOUNTING

S1. Scope

S1.1 This supplement covers single-range noncontact electric and fiber-optic tachometers capable of generating, transmitting, and indicating information or signal that can be converted into a function of rotational speed. The subject tachometers may be used in shipboard systems, such as gas generators, power turbines, propulsion shafts, and gas steam turbine generators.

S1.2 Vibrating reed resonant-type tachometers are not covered in this specification.

S1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

S2. Referenced Documents

S2.1 Commercial Documents:
S2.1.1 ASTM Standards:
B 117 Practice for Operating Salt Spray (Fog) Apparatus
D 3951 Practice for Commercial Packaging
S2.1.2 ANSI/ISA Standards:
ANSI/ISA S37.1 (R-1982) Electrical Transducer Nomenclature and Terminology
S2.1.3 Electronic Industries Association (EIA):
RS-422 Electrical Characteristics of Balanced Voltage Digital Interface Circuit
455-22 FOTP-22 Ambient Light Susceptibility of Fiber Optic Components
455-34 FOTP-34 Interconnection Device Insertion Loss Test
S2.2 Government Documents:
S2.2.1 Military Standards:
MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
S2.2.1.1 Military Specifications:
MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type
MS3456 Connector, Plug, Electrical, Rear Release, Crimp Contact, AN Type
MIL-C-5015 Connectors, Electrical, Circular Threaded, AN Type General Specification
MIL-M-24794 Material, Index Matching, Fiber Optics
MIL-F-49291 Fiber, Optical, (Metric), General Specifications
MIL-C-83522 Connectors, Fiber Optic, Single Terminus, General Specification for
MIL-C-83522/16 Connector, Fiber Optic, Single Terminus, Plug, Adapter Style, 2.5 mm Bayonet Coupling, Epoxy
MIL-C-83522/17 Connector, Fiber Optic, Single Terminus, Adapter, 2.5 mm Bayonet Coupling, Bulkhead Panel Mount
MIL-C-83522/18 Connector Fiber Optic, Single Terminus, Adapter, 2.5 mm Bayonet Coupling, PC Mount
MIL-C-85045 Cables, Fiber Optic, (Metric), General Specification
MIL-S-901 Shock Tests, H.I. (High Impact), Shipboard Machinery, Equipment, and Systems, Requirements for
S3. Terminology

S3.1 Definitions—Terms marked with (ANSI/ISA S37.1) are taken directly from ANSI/ISA S37.1 (R-1982) and are included for the convenience of the reader.
S3.1.1 ambient conditions—conditions, such as pressure and temperature, of the medium surrounding the case of a sensor (ANSI/ISA S37.1).
S3.1.2 calibration—test during which known values of measurands are applied to the sensor and corresponding output readings are recorded under specific conditions (ANSI/ISA S37.1).

3 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
5 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.
S3.1.3 environmental conditions—specified external conditions, such as shock, vibration, and temperature, to which a sensor may be exposed during shipping, storage, handling, and operation (ANSI/ISA S37.1).

S3.1.4 error—the error for a given value of the input variable (measurand) is the difference between the measured value of the output signal and the expected value of the output signal. The expected value of the output signal for any value of the measurand shall be represented by a straight line whose end points are given by:

S3.1.4.1 The specified value of the output signal at the minimum input value of the measurand (for example, 4 mA at the minimum specified rotational speed).

S3.1.4.2 The specified value of the output signal at the maximum input value of the measurand (for example, 20 mA at the maximum specified rotational speed).

S3.1.5 noncontact tachometer—any type of tachometer that senses or responds to rotational speed without physical contact or mechanical connection to the shaft being measured.

S3.1.6 operating environmental conditions—environmental conditions during exposure to which a sensor must perform in some specified manner (ANSI/ISA S37.1).

S3.1.7 optical—involving the use of light-sensitive devices to acquire information.

S3.1.8 optical fiber—a very thin filament or fiber, made of dielectric materials, that is enclosed by material of lower index of refraction and transmits light throughout its length by internal reflections.

S3.1.9 optoelectronics module—a component of the fiber optic tachometer that contains the optical source and detector, and signal conditioner devices necessary to convert the sensed rotational speed to a specified output signal.

S3.1.10 output—electrical or numerical quantity, produced by a sensor or measurement system, that is a function of the applied measurand.

S3.1.11 range—measurand values, over which a sensor is intended to measure, specified by their upper and lower limits (ANSI/ISA S37.1).

S3.1.12 repeatability—ability of a sensor to reproduce output readings when the same measurand value is applied to it consecutively, under the same conditions, and in the same direction (ANSI/ISA S37.1).

S3.1.13 sensor element—that part of the sensor that responds directly to the measurand (ANSI/ISA S37.1).

S3.1.14 sensor head—the transduction element of a fiber optic tachometer that detects rotational speed by means of changes in optical properties.

S3.1.15 sheath—the protective covering of a sensor element.

S3.1.16 signal conditioner—an electronic device that makes the output signal from a transduction element compatible with a readout system.

S3.1.17 span—the algebraic difference between the limits of the measurement range.

S3.1.18 static error band—the maximum deviation from a straight line drawn through the coordinates of the lower range limit at specified sensor output, and the upper range limit at specified output expressed in percentage of sensor span.

S3.1.19 supporting surface—surface on which the equipment is placed.

S3.1.20 target—description including items such as material, size, multiple reflectors, and surface features shall be as specified in the acquisition requirements.

S3.1.21 tachometer—an instrument capable of generating, transmitting, and indicating information or signal that can be converted into a function of rotational speed.

S3.1.22 warm-up time—the time required for a sensor to operate within specified accuracy, repeatability, and other critical parameters after being energized from a cold (ambient) state.

S4. Design Classification

S4.1 Electric Types:

S4.1.1 Designation—Tachometers shall be classified by a series of designations which shall be assigned and listed in the format following.

Example: F 2046-20M-BK-A

<table>
<thead>
<tr>
<th>Specification</th>
<th>Range (see S4.1.2)</th>
<th>Mounting (see S4.1.3)</th>
<th>Indicator (see S4.1.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F 2046</td>
<td>20M</td>
<td>BK</td>
<td>A</td>
</tr>
</tbody>
</table>

S4.1.2 Range—Electric tachometer ranges shall be selected from the standard ranges listed in Table S4.1.

S4.1.3 Mounting—Tachometer indicators shall be either bulkhead mounted (designator—BK) or panel (designator—PL) mounted.

S4.1.4 Indicator—Tachometer indicators shall be either analog (designator—A) or digital (designator—D).

### TABLE S4.1 Standard Ranges for Electric Tachometers

<table>
<thead>
<tr>
<th>Range, RPM</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–100</td>
<td>10A</td>
</tr>
<tr>
<td>0–200</td>
<td>20A</td>
</tr>
<tr>
<td>0–500</td>
<td>50A</td>
</tr>
<tr>
<td>50–500</td>
<td>50M</td>
</tr>
<tr>
<td>0–1000</td>
<td>10B</td>
</tr>
<tr>
<td>100–1000</td>
<td>10M</td>
</tr>
<tr>
<td>0–2000</td>
<td>20B</td>
</tr>
<tr>
<td>200–2000</td>
<td>20M</td>
</tr>
<tr>
<td>0–3000</td>
<td>30B</td>
</tr>
<tr>
<td>300–3000</td>
<td>30M</td>
</tr>
<tr>
<td>0–4000</td>
<td>40B</td>
</tr>
<tr>
<td>0–5000</td>
<td>50B</td>
</tr>
<tr>
<td>500–5000</td>
<td>50N</td>
</tr>
<tr>
<td>0–10 000</td>
<td>10N</td>
</tr>
<tr>
<td>1000–10 000</td>
<td>10N</td>
</tr>
<tr>
<td>0–20 000</td>
<td>20C</td>
</tr>
<tr>
<td>1000–20 000</td>
<td>20N</td>
</tr>
<tr>
<td>0–30 000</td>
<td>30C</td>
</tr>
<tr>
<td>50–500</td>
<td>50C</td>
</tr>
<tr>
<td>500–5000</td>
<td>50P</td>
</tr>
<tr>
<td>0–100 000</td>
<td>10D</td>
</tr>
<tr>
<td>500–100 000</td>
<td>10P</td>
</tr>
<tr>
<td>1000–100 000</td>
<td>10R</td>
</tr>
<tr>
<td>5000–100 000</td>
<td>10T</td>
</tr>
</tbody>
</table>

S4.2 Fiber-Optic Type:

S4.2.1 Designation—The sensor classification shall consist of a series of designations which shall be assigned and listed in the form following.

Example: F 2046-DC-A-1
S4.2.2 Input Power—The input power required to operate the optoelectronics module shall be designated as follows:
dc—28-V direct current (Vdc)
ac—115-V alternating current (Vac)

S4.2.3 Optoelectronics Module—The mounting of the tachometer’s optoelectronics module type shall be designated as follows:
Type A—Bulkhead mounted (see S7.3.1)
Type B—Console mounted (see S7.3.2)

S4.2.4 Sensor Mounting Configuration—The tachometer’s sensor shall be mounted according to the following mount requirement type. The mass per unit length of the sensor mount configuration shall be no greater than 0.02 kg/mm. The dimensions of the tachometer’s sensor head shall be in accordance with Fig. S4.1.

S4.2.4.1 Mass—Unless otherwise specified, the mass of the optoelectronics module shall be not greater than 5 kg.

S4.2.4.2 Target—The target description including items such as material, size, multiple reflectors, and surface features shall be as specified in the acquisition requirements.

S4.2.5 Range—The fiber-optic tachometer range is an internal selection within the optoelectronics module with the following ranges:
0—1000 RPM
0—5000 RPM
0—10 000 RPM
0—20 000 RPM

S5. Ordering Information

S5.1 The buyer shall provide the manufacturer with all of the pertinent application data shown in S5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S5.2 Acquisition Requirements—Acquisition documents shall specify the following:
(a) Title, number, and date of this specification;
(b) Type and quantity required;
(c) Whether panel or bulkhead mounting is required;
(d) Range required;
(e) National Stock Numbers (NSNs) if available;
(f) When self-contained red illumination is required;
(g) Whether tachometer, control box, and indicator should be other than drip-proof construction;
(h) Number of additional indicators, if required;
(i) When qualification testing is required;
(j) Disposition of qualification test samples;
(k) Analog or digital indicator requirement;
(l) Special levels of preservation-packaging and packing required; and
(m) Product marking and labeling required.

S5.2.1 Fiber-Optic Requirements—In addition to the requirements outlined in S5.2, acquisition documents for fiber-optic tachometers should specify the following:
(a) Classification (see S4.2.1):
   (1) Input power,
   (2) Optoelectronics module,
   (3) Signal output, and
   (4) Range.
(b) Whether bulkhead or console mounting is required.
(c) Type and quantity of indicator(s) required.
(d) Whether junction box should be other than drip-proof construction.

S6. Materials and Manufacture

S6.1 Metals—Unless otherwise specified herein, all metals used in the construction of the tachometer shall be corrosion resistant. Dissimilar metals shall not be used in close physical contact with each other unless suitably finished to prevent electrolytic corrosion.

S6.2 Flammable Materials—Materials used in the construction of the tachometer shall, in the end configuration, be noncombustible or retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application.

S6.3 Fungus-Resistant Materials—Materials used in the construction of the tachometer shall be fungus-inert materials.

![Figure S4.1 Sensor Head Construction](image)
S6.4 Solvents, Adhesives, and Cleaning Agents—If any chemicals or cements are used in bonding of internal tachometer components, no degradation of these components shall result during in-service use.

S6.5 Refractive Index Matching Gels, Fluids, or Compounds—Refractive index matching gels, fluids, or compounds for fiber-optic tachometers shall be in accordance with MIL-M-24794.

S7. Physical Properties

S7.1 Electric Tachometers—Electric tachometers shall be a noncontact design and shall provide an output proportional to the continuous instantaneous shaft speed. Tachometers shall be for fixed mounted type of installations in which ranges from 100 to 100 000 RPM are permitted. Unless otherwise specified, the sensor, control box, and indicator shall be of drip-proof construction.

S7.1.1 Sensor—The sensor shall produce a signal by magnetic pulse, light pulse, or other noncontact method for input to the control box. The method of mounting or adapting the sensor may be varied to suit the machinery details.

S7.1.2 Control Box—The control box shall include the necessary electronics to process the sensor signal for driving the indicator. The sensor and control box may be combined in a single unit.

S7.1.3 Indicator—The indicator shall be capable of panel or bulkhead mounting. The indicator shall be analog or digital, as specified in the acquisition requirements. The analog indicator shall be a nominal 4 1/2- or 6-in. round scale with a 250° minimum arc. The digital indicator may be a round or rectangular liquid crystal or light-emitting diode display with readout numerals a minimum of 1 cm in height. A stop shall be provided in analog indicators to prevent the indicating pointer from going past full-scale reading. Analog indicators shall have self-contained red illumination.

S7.1.3.1 Dial and Pointer for Analog Indicators—The dial shall be of a corrosion-resistant material that will not warp at 90°C. The dial shall have a dull white finish with scale markings, numerals, and pointer a dull black. Dial and pointer assembly shall be of commercial design.

S7.1.3.2 Display or Indicator Windows—The display shall be protected by a window of high-quality plastic, free from flaws and defects, that does not cause parallax error.

S7.1.4 Dimensions and Weights (Maximum)—Dimensions and weights of the indicator shall be as shown in Table S7.1.

<table>
<thead>
<tr>
<th>TABLE S7.1 Dimensions and Weight (Indicators)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Scale Length Min, in.</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>4 1/2</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

S7.1.5 Mounting—The indicator shall be designed for panel or bulkhead mounting.

S7.1.6 Operating Characteristics—The tachometers shall instantaneously and continuously indicate information or a signal that can be converted into a function of the speed of rotation in RPM of the rotating part being measured. The tachometers shall indicate, without change or adjustment, regardless of the direction of rotation of the driving part on the same scale.

S7.2 Fiber-Optic Tachometers—The fiber-optic tachometer shall be a noncontact device capable of converting a rotational speed to a continuous output signal throughout a specified measurement range. A fiber-optic tachometer shall consist of a sensor head, optoelectronics module, and fiber-optic cable connector at both ends. The optoelectronics module translates the optical input from the sensor head to a continuous linear proportional analog electrical signal or other output signal such as optical and digital.

S7.2.1 Sensor Head—The sensor head(s) shall be passive and detect shaft rotation through change in optical properties. The beam interruption sensing mechanism shall consist of two sensor heads. One sensor head shall be used to transmit, and one sensor head shall be used to receive an optical signal (generated from the optoelectronics module) across an air gap. Neither electrical nor electronic components shall be used in the construction of the sensor head. The configuration and physical dimensions of the sensor head(s) shall be as specified.

S7.2.2 Optoelectronics Module Mounting—The optoelectronics module mounting shall be either bulkhead or console mounted as specified.

S7.2.2.1 Bulkhead Mounted (Type A)—The optoelectronics module shall be housed in a junction box.

S7.2.2.2 Console Mounted (Type B)—The optoelectronics module shall be packaged in a circuit card that is a modular subassembly of a control console. Design and test requirements for the optoelectronics module shall be as specified.

S7.2.3 Fiber-Optic Cable—For integrity, the cable shall have an outer diameter of a four-fiber cable in accordance with MIL-C-85045. In the cable, there shall be no less than two times the number of fibers needed for operation of the sensor. The cable shall be supplied with a stuffing tube, packing assembly, and an O-ring, installed on each end of the cable to accomplish watertight penetration into the sensor head and optoelectronics module. Exposed single-fiber OFCC shall not be used over distances greater than 1 m. The length of cable shall be as specified.

S7.2.3.1 Optical Fiber—Optical fiber used to transmit light between the optoelectronics unit and the sensor head shall be in accordance with MIL-F-49291.

S7.2.3.2 Fiber-Optic Connectors, Receptacles, and Bulkhead Adapters—Fiber-optic connectors, receptacles, or bulkhead adapters used shall be in accordance with MIL-C-83522 and MIL-C-83522/16, 17, 18, respectively. Connectors shall be assembled at both ends of the fiber-optic cable between the sensor head and the optoelectronics module. The connectors and receptacles shall be mounted inside the sensor head or optoelectronics module.

S7.2.4 Electrical Input Power Requirements—Nominal steady-state power supply requirements for ac shall be 115 ± 8 V, 60 ± 2 Hz, single phase. Nominal steady-state power supply requirements for dc shall be 28 ± 4.5 V. The tachometer shall meet all performance requirements specified herein while operating with specified power supply voltages and their tolerances.
S7.2.5 Output Signal—The output signal of the tachometer shall be directly proportional to the speed being measured. A means shall be provided for internal selection (within the optoelectronics module) between the following output signals: true current source of 4 to 20 mA, 0 to 1 mA, 0 to 2 mA, 0 to 5 mA; true voltage source of 0–5 V or 0–10 V dc, and frequency (including TTL compatibility). A means shall also be provided for internal indication of the output signal selected. The complexity of this adjustment shall be such that one individual working alone is capable of performing this adjustment. The adjustment shall not require electrical disconnection.

S7.2.5.1 Current Output—The 0– or 4–mA output shall correspond to the lower speed range value and the 1–, 2–, 5–, or 20–mA output shall correspond to the upper speed range value. The current output shall remain accurate regardless of external load resistance variations over a range of 0 to 250 Ω.

S7.2.5.2 Voltage Output—The 0–Vdc output shall correspond to the lower speed range value, and the 5– or 10–Vdc output shall correspond to the upper speed range value. The voltage output shall remain accurate regardless of external load resistances greater than 100 000 Ω.

S7.2.5.3 Optical Output—When an optical output is required, all requirements shall be as specified.

S7.2.5.4 Digital Output—When an electrical digital output is required, all requirements shall be as specified. The electrical characteristics shall be in accordance with EIA Standard RS-422 for balanced voltage digital interface circuitry or as specified. The data format shall be as specified.

S7.2.6 Electrical Connectors—A single electrical connector and mating plug in accordance with MIL-C-5015 shall be used to interface the input power and linear output signal to the optoelectronics module. The appropriate connector assembly and pin designations for each of the possible tachometer configurations shall be as follows:

| S7.2.6.1 dc Input and Current or Voltage Output | The receptacle mounted to the optoelectronics module shall be Classification MS3452W14S-5PX in accordance with MS3452. Receptacle Pin “A” shall be +28–Vdc power input, Pin “B” shall be −28–Vdc power input, Pin “C” shall be case ground, Pin “D” shall be a +mA or Vdc signal output, and Pin “E” shall be a −mA or Vdc signal output. The mating plug shall be Classification MS3456W14S-5SX in accordance with MS3456. |
| S7.2.6.2 dc Input and Frequency Output | The receptacle mounted to the optoelectronics module shall be Classification MS3452W14S-5PX in accordance with MS3452. Receptacle Pin “A” shall be +28–Vdc power input, Pin “B” shall be −28–Vdc power input, Pin “C” shall be case ground, and Pins “D” and “E” shall be frequency signal outputs. The mating plug shall be Classification MS3456W14S-5SX in accordance with MS3456. |
| S7.2.6.3 ac Input and Current or Voltage Output | The receptacle mounted to the optoelectronics module shall be Classification MS3452W14S-5PX in accordance with MS3452. Receptacle Pins “A” and “B” shall be 115–Vac power input, Pin “C” shall be case ground, Pin “D” shall be a +mA or Vdc signal output, and Pin “E” shall be a −mA or Vdc signal output. The mating plug shall be Classification MS3456W14S-5SX in accordance with MS3456. |

S7.2.6.4 ac Input and Frequency Output—The receptacle mounted to the optoelectronics module shall be Classification MS3452W14S-5PX in accordance with MS3452. Receptacle Pins “A” and “B” shall be 115–Vac power input, Pin “C” shall be case ground, Pins “D” and “E” shall be frequency signal outputs. The mating plug shall be Classification MS3456W14S-5SX in accordance with MS3456.

S7.2.6.5 Digital Output—The connector assembly for a digital output signal shall be as specified.

S7.2.7 RPM Range Selection—A means shall be provided for internal selection (within the optoelectronics module) between the following rpm ranges: 0 to 1000, 0 to 5000, 0 to 10 000, and 0 to 20 000. A means shall also be provided for internal indication of the rpm range selected. The complexity of this adjustment shall be such that one individual working alone is capable of performing this adjustment. The adjustment shall not require electrical disconnection.

S7.2.8 Low-Intensity Alarm Indication—The optoelectronics module shall have a red LED which shall light when the intensity of the tachometer’s optical signal falls below a preset level. The LED shall be located on either the top or front of the module as it would be mounted during typical usage. The LED shall be visible in typical fluorescent room lighting. The optoelectronics alarm will allow for an indication that maintenance is required before a false output signal from the tachometer.

S7.2.8.1 Low-Intensity Alarm Set Point Adjustment—A means shall be provided for adjusting the low-intensity alarm set point over no less than one half of the dynamic range of the tachometer. A means of securing this adjustment shall be provided. The low-intensity alarm set point shall be capable of adjustment by one individual without the necessity for any electrical disconnection. Alarm set point adjustments shall be labeled and shall be accessible when the optoelectronics enclosure cover is removed.

S7.2.9 Sensitivity Adjustment—The tachometer shall have a sensitivity adjustment for increasing or decreasing the electrical pulse height of the optical signal over the dynamic range of the tachometer. The tachometer’s sensitivity shall be adjustable by one individual without the necessity for any electrical disconnection. Sensitivity adjustments shall be labeled and shall be accessible when the optoelectronics enclosure cover is removed.

S7.2.10 Fuses—The optoelectronics module shall not be fused.

S8. Performance Requirements

S8.1 Accuracy, Repeatability, and Damping—The accuracy of the tachometer shall be no less than 1 % of full-scale reading at any part of the scale at any ambient temperature between 5 and 65°C. The accuracy requirement shall be met during three calibration cycles to demonstrate repeatability. The accuracy requirements shall be met within 2 s of the sensor receiving an input signal and at any temperature between 5 and 65°C to demonstrate damping requirements.

S8.2 Reference Measurement—The referenced accuracy of each of the output signals of the fiber optic tachometer shall be
within ±1.0 % of the output span. Measurements shall be made at 10, 50, and 90 % intervals of span without any alignments or adjustments.

S8.3 Magnetizing—The materials used in the construction of the tachometers shall have such characteristics that no error, either temporary or permanent, in excess of the errors permitted under the accuracy requirements specified for the applicable type will be introduced when the tachometer is tested as specified in S12.2.3. Posttest reference measurements shall meet the requirements of S8.2.

S8.4 Accelerated Life—The tachometers shall be capable of demonstrating reliable operation within the accuracy requirements when subjected to the conditions within the performance parameters yet configured to induce accelerated life conditions (see S12.2.4).

S8.5 Sensitivity (Fiber Optic Only)—The ratio of the tachometer output in percent change of span to speed input in percentage change of span shall not be less than 0.75 or more than 1.25.

S8.6 Response Time (Fiber Optic Only)—The time for the tachometer output signal to indicate a steady-state speed (that is, 5000, 10,000, or 20,000 rpm) shall not be greater than 2 s after the test standard attains a steady-state speed.

S8.7 Warm-Up Time (Fiber Optic Only)—The tachometer shall attain an output value within ±1 % of the output span. Output shall reach this band in no more than 1 min after the tachometer is energized and shall remain in this band.

S8.8 Dynamic Range (Fiber Optic Only)—The dynamic range of the tachometer shall be no less than 35 dB for tachometers using the beam interruption sensing mechanism. The dynamic range of the tachometer shall be no less than 16 dB for tachometers using the reflection and magneto-optic sensing mechanism.

S8.9 Ambient Light Susceptibility (Fiber Optic Only)—This test is applicable for tachometers using the reflection and beam interruption sensing mechanism only. Monitored tachometer output during the ambient light susceptibility test shall show no deviation greater than ±1 % of the output span.

S8.10 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc) (Fiber Optic Only)—The tachometer shall exhibit no damage and shall be in accordance with the requirements of S8.2 during each of the specified test conditions.

S8.11 Transient Voltage and Frequency (ac) or Voltage (dc) (Fiber Optic Only)—The tachometer shall exhibit no damage and reference measurements shall be in accordance with the requirements of S8.2 following each of the transient conditions.

S8.12 Insulation Resistance (Fiber Optic Only)—The insulation resistance of the optoelectronics module shall not be less than 10 MΩ.

S8.13 Power Interruption (Fiber Optic Only)—The tachometer shall exhibit no damage and shall be in accordance with the requirements of S8.2 when power is reapplied following each of the power interruption intervals.

S8.14 Short Circuit (Fiber Optic Only)—The tachometer shall exhibit no damage and shall be in accordance with the requirements of S8.2 following the short-circuit test.

S8.15 Line Voltage Reversal (dc Input) (Fiber Optic Only)—The tachometer shall exhibit no damage and shall be in accordance with the requirements of S8.2 following the line voltage reversal test.

S8.16 Temperature (Fiber Optic Only)—During the temperature test, monitored tachometer output shall show no deviation greater than ±1 % of the output span. Following this test, the tachometer shall be in accordance with the requirements of S8.2.

S8.17 Humidity (Fiber Optic Only)—The tachometer shall be in accordance with the requirements of S8.2 without any alignments or adjustments. After testing is completed, there shall be no evidence of physical degradation, such as corrosion of metal parts or distortion of plastic parts.

S8.18 Enclosure (Fiber Optic Only)—There shall be no evidence of water penetration into the tachometer components either during or at the conclusion of the enclosure test. During the enclosure test, monitored tachometer output shall show no deviation greater than ±1 % of the output span. The tachometer shall be in accordance with the requirements of S8.2 following the enclosure test.

S8.19 Salt Spray (Fiber Optic Only)—Following this test, the tachometer shall show no appreciable corrosion or other damage, either optical, mechanical, or electrical that will affect its operation, and it shall be in accordance with the requirements of S8.2.

S8.20 Vibration—Tachometers shall conform to the vibration requirements of MIL-STD-167-1 (see S12.2.20). Monitored tachometer output during all phases of the vibration test shall show no deviation greater than ±1 % of the output span. Pretest and posttest reference measurements shall be in accordance with the requirements of S8.2. The tachometer shall show no evidence of physical damage that impairs its operation as a result of the vibration test.

S8.21 Shock—Tachometers shall conform to the shock requirements of Type A, Class I, Grade A for lightweight equipment of MIL-S-901. Monitored tachometer output during all phases of the shock test shall show no evidence of physical damage greater than ±1 % of the output span. Pretest and posttest reference measurements shall be in accordance with the requirements of S8.2. The tachometer shall show no evidence of physical damage that impairs its operation as a result of the shock test.

S8.22 Electromagnetic Interference (EMI) Emission and Susceptibility—Tachometers shall conform to the electromagnetic interference requirements of MIL-STD-461 (see S12.2.22). The tachometers shall be in accordance with MIL-STD-461 requirements CE101, CE102, CS101, CS114, CS116, RE101, RS101, RS103, and RS105. Monitored tachometer output during all phases of the EMI test shall show no deviation greater than ±1 % of the output span. Pretest and posttest reference measurements shall be in accordance with the requirements of S8.2.

S9. Workmanship, Finish, and Appearance

S9.1 Cleaning and Surface Finishes—Surfaces of castings, forgings, molded parts, stampings, and machined and welded parts shall be free of defects such as cracks, porosity, undercuts, voids, and gaps as well as sand, dirt, fins, sharp edges,
scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn-through. There shall be no warpage or dimensional change as a result of heat from welding operation.

S10. Inspection

S10.1 Inspection System—The manufacturer shall provide and maintain an inspection system acceptable to the buyer for supplies and services covered by this specification. The testing set forth in this specification shall become a part of the manufacturer’s overall inspection system or quality program. The manufacturer’s quality system shall comply with the requirements of ANSI/ASQC 9001-1994. Certification and registration is highly desired but not required.

S10.2 Classification of Inspections—The inspection requirements specified herein are classified as follows:
(a) Qualification testing and
(b) Quality conformance testing.

S10.3 Qualification Testing—One sample tachometer shall be subjected to the examination and tests specified in Table S10.1. Failure of any tachometer to meet the requirements of this specification shall be cause for rejection.

S10.4 Quality Conformance Testing—Each tachometer shall be subjected to the tests specified in Table S10.2. The results of each examination and test shall be compared to the requirements of this specification. If any tachometer fails in the examination or in any test, it shall be rejected.

S10.5 Order of Inspection—The sample tachometers shall be subjected to the inspections specified in Tables S10.1 and S10.2 in the order listed except that the steady-state supply voltage and frequency inspection may be performed concurrently with the temperature inspection.

<table>
<thead>
<tr>
<th>TABLE S10.1 Qualification Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examination and Test</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>General examination</td>
</tr>
<tr>
<td>Accuracy and repeatability</td>
</tr>
<tr>
<td>Damping</td>
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<tr>
<td>Reference measurement</td>
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<tr>
<td>Magnetizing</td>
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<tr>
<td>Accelerated life</td>
</tr>
<tr>
<td>Sensitivity</td>
</tr>
<tr>
<td>Response time</td>
</tr>
<tr>
<td>Warm-up time</td>
</tr>
<tr>
<td>Dynamic range</td>
</tr>
<tr>
<td>Ambient light susceptibility</td>
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<tr>
<td>Steady-state voltage</td>
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<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Transient voltage</td>
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<tr>
<td>Insulation resistance</td>
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<td>Power interruption</td>
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<td>Enclosure</td>
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<tr>
<td>Salt spray</td>
</tr>
<tr>
<td>Vibration</td>
</tr>
<tr>
<td>Shock</td>
</tr>
<tr>
<td>Electromagnetic interference</td>
</tr>
</tbody>
</table>

S10.6 General Examination—Each tachometer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. Examination shall also include a check of all adjustments. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with the specifications and standards as applicable.

S11. Number of Tests and Retests

S11.1 The number of tests and retests, if any, shall be specified in the acquisition requirements.

S12. Test Methods

S12.1 Test Conditions—Unless otherwise specified herein, the fiber-optic tachometer(s) shall be fully assembled and energized throughout the duration of each test procedure. Except where the following factors are the variables, the tests specified in S10.2 shall be conducted with the equipment under the following operating environmental conditions:
(a) Ambient temperature shall be 25 ± 5°C,
(b) Relative humidity shall be ambient,
(c) Supply voltage shall be 115 V (nominal) for input power designation ac or 28 V (nominal) for input power designation dc,
(d) Supply frequency shall be 60 Hz (nominal) for input power designation ac or dc for input power designation dc,
(e) Distance from sensor head to target shall be 10 mm for fiber-optic tachometers using reflection and beam interruption sensing mechanisms, and
(f) Distance from sensor head to target shall be 2 mm for fiber-optic tachometers using magneto-optic sensing mechanism.

S12.2 Test Methods:

S12.2.1 Accuracy—The tachometer shall first be operated over its full speed range by slowly increasing and decreasing the applied speed in four continuous cycles. The calibration measurements shall be made at a minimum often equally spaced intervals over the full range. This calibration procedure shall be applied three successive times to determine repeatability. The fiber optic tachometer shall be energized and operational at a speed range setting of 0 to 20 000 rpm. A measurement of each of the outputs of the optoelectronics module shall be performed at the following speeds: 5000, 10 000, 15 000, and 20 000 rpm. This measurement shall be performed three successive times for each of the optoelectronics module outputs (see S8.2). The maximum difference
between any two output values at the same speed for each of the optoelectronics module output signal selections shall determine repeatability. Accuracy, repeatability, and damping shall meet the requirements of S8.1.

S12.2.1.1 Temperature—Accuracy tests shall be conducted at 5, 25, and 65°C. The accuracy shall be checked at a minimum of five equally spaced operating speeds over the range of the tachometer. The tachometer shall conform to the accuracy requirements of S8.1.

S12.2.2 Reference Measurement—The tachometer shall be energized and operational. A measurement shall be made at 10, 50, and 90 % intervals of span both upscale and downside. The accuracy at all points of measurement shall meet the requirements of S12.2.1.

S12.2.3 Magnetizing—While operating at a constant speed of approximately 50 % of full-scale range, the tachometer shall be placed in varying positions in a unidirectional, magnetic field having a flux density in free air of approximately 5 gausses. The error of tachometers shall be within the requirements specified in S8.2.

S12.2.4 Accelerated Life—Tachometers shall be operated at a constant speed approximately equal to the midpoint of their range for four periods. The periods shall be as follows:

<table>
<thead>
<tr>
<th>Period</th>
<th>Duration</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25 h</td>
<td>25°C</td>
</tr>
<tr>
<td>2</td>
<td>25 h</td>
<td>5°C</td>
</tr>
<tr>
<td>3</td>
<td>25 h</td>
<td>65°C</td>
</tr>
<tr>
<td>4</td>
<td>25 h</td>
<td>25°C</td>
</tr>
</tbody>
</table>

Relative humidity shall be varied during Periods 2 and 3 between approximately 50 and 90 % in alternate hour periods. All tachometers shall operate satisfactorily during these tests within their required accuracy as specified in S8.1.

S12.2.5 Sensitivity (Fiber Optic Only)—The sensitivity factor shall be determined using the following procedure:
(a) The tachometer shall be energized and operational at an output signal, of the 0- to 10-V setting corresponding to a speed of 3000 rpm. The tachometer’s speed range setting shall be 0 to 10 000 rpm.
(b) Measure both the shaft speed and the optoelectronics module output signal.
(c) Increase the shaft speed by an amount not greater than 1 % of the output span.
(d) Measure both the new shaft speed and the optoelectronics module output signal.
(e) Calculate the change in both shaft speed and the optoelectronics module output signal as a percentage of the output span.
(f) Determine the ratio of the output percentage change to applied shaft speed percentage change in terms of the output span.
(g) Repeat this procedure for shaft speed decrease not greater than 1 % of the output span.

S12.2.6 Response Time (Fiber Optic Only)—The response time shall be determined by the following procedure:
(a) Energize the fiber optic tachometer and set the position of the sensor head.
(b) Adjust the tachometer’s output signal to the 0- to 10-V setting and the rpm setting to the 0- to 10 000-rpm range.
(c) Energize the test standard and increase the speed of its rotating target to 5000 rpm. The test standard shall reach 5000 rpm within 2 s.
(d) Monitor the output signal of the tachometer and the test standard during the test.

S12.2.7 Warm-Up Time—The warm-up time shall be determined by the following procedure:
(a) Allow the tachometer output signal to stabilize at a value, of the 0- to 5-V setting, corresponding to a measurand operating speed of 800 rpm. The tachometer’s speed range setting shall be 0 to 1000 rpm.
(b) Deenergize the tachometer for no less than 2 h.
(c) Reenergize the tachometer and monitor the optoelectronics module output as necessary to ensure tachometer meets the requirements of S8.7.

S12.2.8 Dynamic Range (Fiber Optic Only)—The dynamic range of the optoelectronics module shall be tested in accordance with the following procedures:

S12.2.8.1 Beam Interruption—A calibrated optical attenuator with two jumpers shall be tested for insertion loss in accordance with EIA-455-34. The attenuator shall then be connected between the optoelectronics module and the sensor head of the transmitting optical signal by means of the two jumper cables. The tachometer’s sensitivity shall be adjusted to the maximum setting. The attenuation shall be increased from 0 dB (encompassing insertion loss of attenuator and jumpers) to 35 dB. The tachometer shall be operating at an output signal value, of the 0- to 5-V setting, corresponding to an operating speed of 800 rpm. The tachometer’s speed range setting shall be 0 to 1000 rpm. The dynamic range will be exceeded when the output signal drops to a value equivalent to 0 rpm. Performance shall be in accordance with the requirements of S8.8.

S12.2.8.2 Reflection and Magneto-Optic Effect—A calibrated optical attenuator with two jumpers shall be tested for insertion loss in accordance with EIA-455-34. The attenuator shall be connected between the optoelectronics module and the sensor head via the two jumper cables. The tachometer’s sensitivity shall be adjusted to the maximum setting. The attenuation shall increase from 0 dB (encompassing insertion loss of attenuator and jumpers) to 16 dB. The tachometer shall be operating at an output signal value, of the 0- to 5-V setting, corresponding to an operating speed of 800 rpm. The tachometer’s speed range setting shall be 0 to 1000 rpm. The dynamic range will be exceeded when the output signal drops to a value equivalent to 0 rpm. Performance shall be in accordance with the requirements of S8.8.

S12.2.9 Ambient Light Susceptibility (Fiber Optic Only)—The ambient light source and general test conditions shall be in accordance with EIA-455-22. The tachometer shall be energized and placed in the beam of the light source for a 10-min duration. During the test, the tachometer shall be energized and operational at an output signal, of the 0- to 5-V setting, corresponding to a speed of 3000 rpm. The tachometer’s speed range setting shall be 0 to 10 000 rpm. This output shall be monitored during the test. Performance shall be in accordance with the requirements of S8.9.

S12.2.10 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc) (Fiber Optic Only)—This test may be performed in conjunction with the temperature test (see
S12.2.16). For ac-powered tachometers, a reference measurement shall be performed at 0, 25, and 65°C for each of the conditions specified in S12.2.11.1 and S12.2.11.2. For dc-powered tachometers, a reference measurement shall be performed at 0, 25, and 65°C for each of the conditions specified in S12.2.11.3. The tachometer shall be allowed to stabilize at each testing temperature before the reference measurements are performed. Performance shall be in accordance with the requirements of S8.10.

S12.2.11 Transient Voltage and Frequency (ac) or Voltage (dc) (Fiber Optic Only)—Ac-powered tachometers shall be tested in accordance with S12.2.11.1 and S12.2.11.2. Dc-powered tachometers shall be tested in accordance with S12.2.11.3.

S12.2.11.1 Transient Voltage (ac):

S12.2.11.1.1 Upper Limit—With the tachometer operating at the steady-state voltage of 123 Vac, the voltage shall be increased to 138 Vac and then decreased back to the steady-state voltage of 123 Vac in a 2-s period. A reference measurement shall then be performed at 115 Vac. The tachometer shall be in accordance with the requirements of S8.2.

S12.2.11.1.2 Lower Limit—With the switch operating at a steady-state voltage of 107 Vac, the voltage shall be decreased to 92 Vac and then increased back to the steady-state voltage of 107 Vac in a 2-s period. A reference measurement shall then be performed at 115 Vac. The tachometer shall be in accordance with the requirements of S8.2.

S12.2.11.2 Transient Frequency (ac):

S12.2.11.2.1 Upper Limit—With the tachometer operating at a steady-state frequency of 62 Hz, the frequency shall be increased to 63.5 Hz and then decreased back to the steady-state frequency of 62 Hz in a 2-s period. A reference measurement shall then be performed at 60 Hz. The tachometer shall be in accordance with the requirements of S8.2.

S12.2.11.2.2 Lower Limit—With the tachometer operating at a steady-state frequency of 58 Hz, the frequency shall be decreased to 56.5 Hz and then increased back to the steady-state frequency of 58 Hz in a 2-s period. A reference measurement shall then be performed at 60 Hz. The tachometer shall meet the requirements of S8.2.

S12.2.11.3 Transient Voltage (dc):

S12.2.11.3.1 Upper Limit—With the tachometer operating at a steady-state voltage of 32.5 Vdc, the voltage shall be increased to 34.5 Vdc and then decreased back to the steady-state voltage of 32.5 Vdc in a 2-s period. A reference measurement shall then be performed at 28 Vdc. The tachometer shall be in accordance with the requirements of S8.2.

S12.2.11.3.2 Lower Limit—With the tachometer operating at a steady-state voltage of 23.5 Vdc, the voltage shall be decreased to 21.5 Vdc and then increased back to the steady-state voltage of 23.5 Vdc in a 2-s period. A reference measurement shall then be performed at 28 Vdc. The tachometer shall be in accordance with the requirements of S8.2.

S12.2.12 Insulation Resistance (Fiber Optic Only)—The insulation resistance of the optoelectronics module shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The temperature shall be 25 ± 5°C and the relative humidity shall be 50 ± 10%. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. If the indication of insulation resistance meets the specified limit and is steady or increasing, the test may be terminated before the end of the 2-min period. The tachometer shall be in accordance with the requirements of S8.12.

S12.2.13 Power Interruption (Fiber Optic Only)—With the tachometer operating within the steady-state tolerances of voltage and frequency, the external power supply shall be suddenly interrupted. After an interval of between 3 and 4 s, the power supply, within the steady-state tolerances, shall be reapplied. After the tachometer has been operated long enough to detect any major performance degradation, the power shall be interrupted for an interval of no less than 30 s. This cycle, (3- to 4-s interruption, monitor, then an interruption of no less than 30 s) shall be repeated three times (four total cycles). Following each of the power interruption intervals, a reference measurement shall be made. The tachometer shall be in accordance with the requirements of S8.13.

S12.2.14 Short Circuit (Fiber Optic Only)—The tachometer shall be deenergized and the positive and negative electrical output leads or terminals of the optoelectronics module shall be connected directly together with no load resistance. The tachometer shall be energized for 5 min, then deenergized, and the short circuit removed. The tachometer shall be energized and a reference measurement shall be made at ambient temperature. The tachometer shall meet the requirements of S8.14.

S12.2.15 Line Voltage Reversal (for dc Powered Tachometers) (Fiber Optic Only)—A positive 28-Vdc signal shall be applied to connector Pin “B.” The dc reference signal shall be applied to connector Pin “A.” The power supply shall be energized for a period of 10 min and then shall be disconnected. The power supply shall then be correctly applied (Pin A positive, Pin B negative) and a reference measurement shall be made. The tachometer shall be in accordance with the requirements of S8.15.

S12.2.16 Temperature (Fiber Optic Only)—The tachometer shall be positioned in an environmental chamber in an energized state and shall be subjected to the following test procedure. Performance shall meet the requirements of S8.16.

(a) Hold test temperature at 0°C for no less than 24 h.
(b) Increase test temperature in steps of 10°C each, at 30 min for each step, until plus 65 ± 2°C is reached. Hold at that temperature for no less than 24 h.
(c) Reduce test temperature in steps of 10°C each, at 30 min for each step, until plus 25 ± 2°C is reached. Hold at that temperature for no less than 24 h.

During the last hour of operation at each temperature plateau (0, 65, and 25°C) the tachometer electrical output signal, of the 0- to 5-V setting, shall be measured corresponding to a speed of 3000 rpm. The tachometer’s speed range setting shall be 0 to 10 000 rpm. After the temperature test, a reference measurement shall be made. Performance shall be in accordance with the requirements of S8.16.

S12.2.17 Humidity (Fiber Optic Only)—The tachometer shall be subjected to the conditioning and tests specified in
S12.2.17.1 through S12.2.17.5. The tachometer shall be energized throughout the test. Performance shall be in accordance with the requirements of S8.17.

S12.2.17.1 Conditioning—To establish a reference condition for the measurement of operating parameters and a valid basis for comparison of the effects of the conditioning to follow, the complete equipment shall be dried at a temperature no less than 40°C or more than 500°C for no less than 2 h.

S12.2.17.2 Reference Measurements—Following the conditioning, a reference measurement shall be made at 25 ± 5°C and 50 ± 5% relative humidity. Performance shall be in accordance with the requirements of S8.17.

S12.2.17.3 Temperature Cycling—The tachometer shall then be subjected to four 24-h cycles of temperature variation consisting of 18 h at 65 ± 5°C and 6 h at 25 ± 5°C. The relative humidity shall be maintained at 90 to 95% (noncondensing) during the steady-state conditions. The transitions between temperatures shall be accomplished within the 6-h period so that the time at the high temperature is 18 h. Each transition shall be not greater than 1 h if the tachometer remains in the chamber or 15 min if a two-chamber method is used. The relative humidity need not be controlled during the transition periods.

S12.2.17.4 Measurement During Cycling—During the second cycle, a reference measurement shall be made at the end of the high temperature period with the tachometer remaining in the chamber at 65 ± 5°C. The tachometer shall be energized for as brief a period as required to complete the measurements.

S12.2.17.5 Measurements After Temperature Cycling—After the four complete cycles, a reference measurement shall be made at 25 ± 5°C with the tachometer remaining in the chamber. Performance shall meet the requirements of S8.17.

S12.2.18 Enclosure (Fiber Optic Only)—The tachometer shall be placed or mounted in a position typical of that for which it was designed. The surface upon which the equipment is placed or mounted (supporting surface) shall extend no less than 1 m beyond the equipment on all sides so that splashing may be produced by directing the water stream on the supporting surface. The water stream shall be a coarse spray with a flow rate of no less than 55 L/min and a head pressure of no less than 3 m. A head pressure of 3 m is defined as sufficient water pressure so that if directed straight up, the stream of water shall rise to a height of 3 m. The distance from the nozzle to the enclosure under test shall be approximately 2 m. The time of the test shall be no less than 5 min with approximately equal portions of time for spray on each surface, including joints of the enclosure and at the supporting surface. During the test, the tachometer shall be energized and operational at an output signal, of the 0- to 5-V setting, corresponding to a speed of 3000 rpm. This output signal shall be monitored during the test. After exposure to vibration, a reference measurement shall be made. Performance shall be in accordance with the requirements of S8.20.

S12.2.19 Salt Spray (Fiber Optic Only)—Before exposure to salt spray, a reference measurement shall be made. The fiber-optic tachometer shall be deenergized and tested in accordance with Practice B 117. Duration of the test shall be 96 h. The tachometer’s major components shall be disassembled at the immediate conclusion of the test and examined for corrosion and moisture penetration. After exposure to salt spray, the tachometer shall be energized and a reference measurement shall be made. Performance shall be in accordance with the requirements of S8.19.

S12.2.20 Vibration—Before exposure to vibration, a reference measurement shall be made. The tachometer shall be exposed to Type I vibration in accordance with MIL-STD-167-1. During vibration, the electric tachometer shall be energized and operational at a speed corresponding to the midpoint of full scale. During vibration, the fiber-optic tachometer shall be energized and operational at an output signal, of the 0- to 5-V setting, corresponding to a speed of 3000 rpm. The tachometer’s speed range setting shall be 0 to 10 000 rpm. This output signal shall be monitored during the test. After exposure to vibration, a reference measurement shall be made. Performance shall be in accordance with the requirements of S8.21.

S12.2.21 Shock—Before shock, a reference measurement shall be made. Electric tachometers shall be subjected to the Type A, Grade A, Class I, lightweight equipment test of MIL-S-901. During shock, electric tachometers shall be energized and operational at a speed corresponding to the midpoint of full scale. The fiber-optic tachometer equipment shall be exposed to shock in accordance with MIL-S-901, Grade A, Type C, Class I. The equipment shall be mounted on Fixture 4A simulating shipboard installation. During shock, the tachometer shall be energized and operational at an output signal, of the 0- to 5-V setting, corresponding to a speed of 3000 rpm. The tachometer’s speed range setting shall be 0 to 10 000 rpm. This output signal shall be monitored during shock. After exposure to shock, a reference measurement shall be made. Performance shall be in accordance with the requirements of S8.22.

S12.2.22 Electromagnetic Interference (EMI) Emission and Susceptibility—The tachometers shall be exposed to EMI in accordance with MIL-STD-461. During exposure to EMI, the electric tachometer shall be energized and operational at a speed corresponding to the midpoint of full scale. During exposure to EMI, the fiber-optic tachometer shall be energized and operational at an output signal, of the 0- to 5-V setting, corresponding to a speed of 3000 rpm. The tachometer’s speed range setting shall be 0 to 10 000 rpm. This output signal shall be monitored during exposure to EMI. After exposure to EMI, a reference measurement shall be made. Performance shall be in accordance with the requirements of S8.22.


S13.1 Warranty—Special warranty requirements shall be specified in the acquisition requirements. Otherwise, the standard commercial warranty applies.

S14. Certification

S14.1 When specified in the purchase order or contract, the buyer shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification, and the requirements have been met. When specified in the purchase order or contract, a report of the test result shall be furnished. It is recommended that all test data
remain on file for three years at the manufacturer’s facility for review by buyer upon request.

**S15. Product Marking**

S15.1 Unique product marking requirements shall be specified in the acquisition requirements.

S15.2 **Fiber-Optic Tachometers:**

S15.2.1 **Optoelectronics Module**—Each optoelectronics module shall be permanently and legibly marked. The following minimum information shall be provided:

- (a) Nomenclature,
- (b) Design classification,
- (c) National Stock Number (NSN) if available,
- (d) Manufacturer’s name and model number,
- (e) Technical manual number,
- (f) Contract number, and
- (g) A unique serial number from the manufacturer.

S15.2.2 **Sensor Head**—Each sensor head shall be permanently and legibly marked in accordance with Practice D 3951. The following minimum information shall be provided:

- (a) Nomenclature,
- (b) Design classification,
- (c) National Stock Number (NSN) if available,
- (d) Manufacturer’s name and model number, and
- (e) A unique serial number from the manufacturer.

S15.2.3 **Labeling**—If laser radiation is used, a visible label shall be affixed to the outside of the optoelectronics module cover and shall contain the following:

**NOTICE**

**UNTERMINATED OPTICAL CONNECTIONS MAY EMIT LASER RADIATION. DO NOT VIEW BEAM WITH OPTICAL INSTRUMENTS AND AVOID DIRECT EXPOSURE TO THE BEAM.**

A visible label with yellow lettering on a black background shall be affixed to the sensor head and the inside of the optoelectronics module and shall contain the following:

**WARNING**

**INVISIBLE LASER RADIATION AVOID EXPOSURE TO THE BEAM**

S15.2.3.1 **Alternating Current**—Optoelectronics modules with input power designation ac shall be permanently and legibly marked with the following label:

**“WARNING 115VAC”**

**S16. Packaging and Package Marking**

S16.1 **Packing Requirements**—Tachometer equipment shall be preserved, packaged, and marked in accordance with Practice D 3951. Bar codes and other applicable packing acquisition options shall be specified.

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Standard Specification for Transducers, Pressure and Differential, Pressure, Electrical and Fiber-Optic

This standard is issued under the fixed designation F 2070; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the requirements for pressure and differential pressure transducers for general applications.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only. Where information is to be specified, it shall be stated in SI units.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.

1.4 Special requirements for naval shipboard applications are included in Supplementary Requirements S1, S2, and S3.

2. Referenced Documents

2.1 ASTM Standards:
D 3951 Practice for Commercial Packaging

2.2 ANSI/ISA Standards:
ANSI/ISA S37.1 Electrical Transducer Nomenclature and Terminology

2.3 ISO Standard:
ISO 9001 Quality System—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing

3. Terminology

3.1 Terms marked with (ANSI/ISA S37.1) are taken directly from ANSI/ISA S37.1 (R-1982) and are included for the convenience of the user.

Definitions—Terminology consistent with ANSI/ISA S37.1 shall apply, except as modified by the definitions listed as follows:

3.1.1 absolute pressure—pressure measured relative to zero pressure (vacuum) (ANSI/ISA S37.1)

3.1.2 ambient conditions—conditions such as pressure and temperature of the medium surrounding the case of the transducer (ANSI/ISA S37.1)

3.1.3 burst pressure—the maximum pressure applied to the transducer sensing element without rupture of the sensing element or transducer case as specified

3.1.4 calibration—the test during which known values of measurands are applied to the transducer and corresponding output readings are recorded under specified conditions (ANSI/ISA S37.1)

3.1.5 common mode pressure—the common mode pressure is static line pressure applied simultaneously to both pressure sides of the transducer for the differential pressure transducer only

3.1.6 differential pressure—the difference in pressure between two points of measurement (ANSI/ISA S37.1)

3.1.7 environmental conditions—specified external conditions, such as shock, vibration, and temperature, to which a transducer may be exposed during shipping, storage, handling, and operation (ANSI/ISA S37.1)

3.1.8 error—the algebraic difference between the indicated value and the true value of the measurand (ANSI/ISA S37.1)

3.1.9 fiber-optic pressure transducer—a device that converts fluid pressure, by means of changes in fiber-optic properties, to an output that is a function of the applied measurand. The fiber-optic pressure transducer normally consists of a sensor head, optoelectronics module, and connectorized fiber-optic cable

3.1.10 hysteresis—the maximum difference in output, at any measurand value within the specified range, when the value is approached first with increasing and then with decreasing measurand (ANSI/ISA S37.1)

3.1.11 insulation resistance—the resistance measured between insulated portions of a transducer and between the insulated portions of a transducer and ground when a specified dc voltage is applied under specified conditions

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3 Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
4 Available from International Organization for Standardization, Case Postale 56, Geneve, Switzerland CH-1211.
3.1.12 line pressure—the pressure relative to which a differential pressure transducer measures pressure. 

   (ANSI/ISA S37.1)

3.1.13 operating environmental conditions—environmental conditions during exposure to which a transducer must perform in some specified manner. 

   (ANSI/ISA S37.1)

3.1.14 optical—involving the use of light-sensitive devices to acquire information.

3.1.15 optical fiber—a very thin filament or fiber, made of dielectric materials, that is enclosed by material of lower index of refraction and transmits light throughout its length by internal reflections.

3.1.16 optoelectronics module—a component of the fiber-optic pressure transducer that contains the optical source and detector, and signal conditioner devices necessary to convert the sensed pressure to the specified output signal.

3.1.17 output—electrical or numerical quantity, produced by a transducer or measurement system, that is a function of the applied measurand.

3.1.18 overpressure—the maximum magnitude of a measurand that can be applied to a transducer without causing a change in performance beyond the specified tolerance.

3.1.19 pressure cycling—the specified minimum number of specified periodic pressure changes over which a transducer will operate and meet the specified performance.

3.1.20 pressure rating—the maximum allowable applied pressure of a differential pressure transducer.

3.1.21 process medium—the measured fluid (measurand) that comes in contact with the sensing element.

3.1.22 range—measurand values, over which a transducer is intended to measure, specified by their upper and lower limits. 

   (ANSI/ISA S37.1)

3.1.23 repeatability—ability of a transducer to reproduce output readings when the same measurand value is applied to it consecutively, under the same conditions, and in the same direction. 

   (ANSI/ISA S37.1)

3.1.24 response—the measured output of a transducer to a specified change in measurand.

3.1.25 ripple—the peak-to-peak ac component of the dc output.

3.1.26 sensing element—that part of the transducer that responds directly to the measurand. 

   (ANSI/ISA S37.1)

3.1.27 sensitivity factor—the ratio of the change in transducer output to a change in the value of the measurand.

3.1.28 sensor head—the transduction element of the fiber-optic pressure transducer that detects fluid pressure by means of changes in optical properties.

3.1.29 signal conditioner—an electronic device that makes the output signal from a transduction element compatible with a readout system.

3.1.30 static error band—static error band is the maximum deviation from a straight line drawn through the coordinates of the lower range limit at specified transducer output, and the upper range limit at specified transducer output expressed in percent of transducer span.

3.1.31 transducer—device that provides a usable output in response to a specified measurand. 

   (ANSI/ISA S37.1)

3.1.32 wetted parts—transducer components with at least one surface in direct contact with the process medium.

4. Classification

4.1 Designation—Most transducer manufacturers use designations or systematic numbering or identifying codes. Once understood, these designations could aid the purchaser in quickly identifying the transducer type, range, application, and other parameters.

4.2 Design—Pressure transducers typically consist of a sensing element that is in contact with the process medium and a transduction element that modifies the signal from the sensing element to produce an electrical or optical output. Some parts of the transducer may be hermetically sealed if those parts are sensitive to and may be exposed to moisture. Pressure connections must be threaded with appropriate fittings to connect the transducer to standard pipe fittings or to other appropriate leak-proof fittings. The output cable must be securely fastened to the body of the transducer. A variety of sensing elements are used in pressure transducers. The most common elements are diaphragms, bellows, capsules, Bourdon tubes, and piezoelectric crystals. The function of the sensing element is to produce a measurable response to applied pressure or vacuum. The response may be sensed directly on the element or a separate sensor may be used to detect element response. The following is a brief introduction to the major pressure sensing technology design categories.

4.2.1 Electrical Pressure Transducers:

4.2.1.1 Differential Transformer Transducer—Linear variable differential transformers (LVDT) are variable reluctance devices. Pressure-induced sensor movement, usually transmitted through a mechanical linkage, moves a core within a differential transformer. Sensors are most commonly bellows, capsules, or Bourdon tubes. The movement of the core within the differential transformer results in a change in reluctance that translates to a voltage output. An amplifying mechanical linkage may be used to obtain adequate core movement.

4.2.1.2 Potentiometric Transducer—Pressure-induced movement of the sensing element causes movement of a potentiometer wiper resulting in a change in resistance which translates to a voltage output. A bellows or Bourdon tube is commonly used as the sensing element. An amplifying mechanical linkage may be used to obtain accurate wiper movement.

4.2.1.3 Strain Gage Transducer—Typical strain gage pressure transducers convert a pressure into a change in resistance due to strain which translates to a relative voltage output. Pressure-induced movement in the sensing element deforms strain elements. The strain elements of a typical strain gage pressure transducer are active arms of a Wheatstone Bridge arrangement. As pressure increases, the bridge becomes electrically unbalanced as a result of the deformation of the strain elements providing a change in voltage output.

4.2.1.4 Variable Capacitance Transducer—Variable capacitance pressure transducers sense changes in capacitance with changes in pressure. Typically, a diaphragm is positioned between two stator plates. Pressure-induced diaphragm deflection changes the circuit capacitance, which is detected and translated into a change in voltage output.
4.2.1.5 Variable Reluctance Transducer—Variable reluctance pressure transducers sense changes in reluctance with changes in pressure. Typically, a diaphragm is positioned between two ferric core coil sensors that when excited produce a magnetic field. Pressure-induced diaphragm deflection changes the reluctance, which is detected and translated to a change in voltage output.

4.2.1.6 Piezoelectric Transducer—Piezoelectric transducers consist of crystals made of quartz, tourmaline, or ceramic material. Pressure-induced changes in crystal electrical properties cause the crystal to produce an electrical output which is detected and translated to a change in voltage output.

4.2.2 Fiber-Optic Pressure Transducers:

4.2.2.1 Fabry-Perot Interferometer—Fabry-Perot interferometers (FPI) consist of two mirrors facing each other, the space between the mirrors being called the cavity length. Light reflected in the FPI is wavelength modulated in exact accordance with the cavity length. Pressure-induced movement of one of the mirrors causes a measurable change in cavity length and a phase change in the reflected light signal. This change is optically detected and processed.

4.2.2.2 Bragg Grating Interferometer—A Bragg grating is contained in a section about 1 cm long and acts as a narrow band filter that detects variation in the optical properties of the fiber. When the fiber is illuminated with an ordinary light source such as an LED, only a narrow band of light will be reflected back from the grating section of the fiber. If a pressure is applied to the grating section of the fiber, the grating period changes, and hence, the wavelength of the reflected light, which can be measured.

4.2.2.3 Quartz Resonators—Typically, a pair of quartz resonators are inside the pressure transducer. These are excited by the incoming optical signal. One resonator is load-sensitive and vibrates at a frequency determined by the applied pressure. The second resonator vibrates at a frequency that varies with the internal temperature of the transducer. Optical frequency signals from the resonators are transmitted back to the optoelectronics interface unit. The interface unit provides an output of temperature-compensated pressure.

4.2.2.4 Micromachined Membrane/Diaphragm Deflection—The sensing element is made on a silicon substrate using photolithographic micromachining. The deflection of this micromachined membrane is detected and measured using light. The light is delivered to the sensor head through an optical fiber. The light returning from the membrane is proportional to the pressure deflection of the membrane and is delivered back to a detector through an optical fiber. The fiber and the sensor head are packaged within a thin tubing.

4.3 Types—The following are common types of pressure and differential pressure transducers: pressure, differential; pressure (gage, absolute and sealed); pressure, vacuum; and pressure, compound.

4.4 Process Medium—The following are the most common types of process media: freshwater, oil, condensate, steam, nitrogen and other inert gases, seawater, flue gas and ammonia, and oxygen.

4.5 Application—The following is provided as a general comparison of different types of transducers and considerations for application.

4.5.1 LVDT Transducer—The sensor element may become complicated depending on the amount of motion required for core displacement. Careful consideration should be exercised when the application includes very low- or high-pressure measurement, overpressure exposure, or high levels of vibration. Careful consideration should also be exercised when measuring differential pressure of process media having high dielectric constants, especially liquid media. If the process media is allowed to enter the gap between the sensor element and core, accuracy may suffer. Frequency response may suffer depending on the type of mechanical linkage(s) used in the transducer.

4.5.2 Potentiometric Pressure Transducer—Potentiometric pressure transducers are generally less complicated than other designs. Careful consideration should be exercised when the application includes very low pressure measurement, overpressure exposure, high levels of vibration, stability and repeatability over extended periods of time, or extremely high resolution requirements. Frequency response may suffer depending on the type of mechanical linkage(s) used. Technological advances have yielded more reliable designs that are commonly used.

4.5.3 Strain Gage Transducers—Low-level output strain gage transducers are among the most common pressure transducers. They are available in very compact packages which lend well in applications in which size is critical. Strain gage transducers that demonstrate high degrees of accuracy and excellent frequency response characteristics are readily available. Careful consideration should be exercised when the application includes very low-pressure measurement, very low lag or delay, high vibration levels, extreme overpressure requirements, or critical stability over extended periods.

4.5.4 Variable Capacitance Transducers—Variable capacitance transducers are well suited to measure dry, clean gases at very low pressures with a high degree of accuracy. Careful consideration should be exercised when measuring differential pressure of process media having high dielectric constants, especially liquid media. If the process media is allowed to enter the gap between the diaphragm and stators, accuracy may suffer. Process media that alters the dielectric constant between the diaphragm and stators also alters the output of the transducer unless isolation devices such as membranes or oil fills are used.

4.5.5 Variable Reluctance Transducers—Variable reluctance transducers are well suited to measure most process media, especially if the core coil sensors are isolated from the process media. Variable reluctance transducers are well suited for applications that include high shock or vibration levels, extreme overpressure requirements, high degrees of accuracy, or critical stability over extended periods. Careful consideration should be exercised when evaluating size, weight, and cost. All reluctance devices are affected by strong magnetic fields.

4.5.6 Piezoelectric Transducers—Piezoelectric transducers are very effective in measuring changes in pressure. The piezoelectric crystals only produce an output when they
experience a change in load. With adequate signal conditioners they can also be used to perform static measurements.

5.2.7 *Fiber-Optic Pressure Transducers*—Fiber-optic pressure transducers can be used in virtually all applications. They are extremely sensitive and are beneficial for high resolution measurements. They are unaffected by electromagnetic interference and are recommended in applications where EMI is a problem. These transducers are by nature intrinsically safe and are especially applicable for hazardous environments.

4.6 *Range*—Each manufacturer of transducers advertises a standard operating range for their offered selections but there is no industry-wide standard of specific ranges for transducers. Ranges are available that cover applications from vacuums to 210 MPaG (30 000 psig). Refer to individual manufacturer recommendations on range best suited to each application or specify an exact range if the range is a critical characteristic.

4.7 *Pressure Rating*—Pressure rating applies only to differential pressure transducers. Differential pressure transducers must be selected with a pressure rating for the maximum media pressure to be encountered. The purchaser should refer to specific manufacturer guidance to ensure a transducer has the proper pressure rating for each intended application.

4.8 *Power Supply*—Power supplies furnish excitation to the transducer. Power supplies may include batteries; line-powered, electronically regulated, dc power supplies; or ac power directly from the power system.

4.9 *Output*—Output signals can be electrical or optical dependent on design. Output must be measurable and must correspond with pressure applied within the range of the transducer. Multiple output signals shall be provided when specified. One signal shall be designated as the prime and the other as supplemental.

4.10 *Pressure Connection*—The pressure connection is the opening of the transducer used to allow the process medium to reach the sensing element. Differential pressure transducers have two pressure connections, a high-pressure port and a low-pressure port.

5. **Ordering Information**

5.1 The purchaser should provide the manufacturer with all of the pertinent application data shown in accordance with 5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they should also be described.

5.2 *Acquisition Requirements*—Acquisition documents should specify the following:

- 5.2.1 Title, number, and date of this specification,
- 5.2.2 Manufacturer’s part number,
- 5.2.3 Range, pressure rating (differential only), power supply, output,
- 5.2.4 Mounting method (see 7.2),
- 5.2.5 Type of pressure connection (see 7.5),
- 5.2.6 Type of electrical connection (see 7.4),
- 5.2.7 When an electrical connection mating plug is not to be provided (see 7.4),
- 5.2.8 System process medium,
- 5.2.9 Prime output signal,
- 5.2.10 Supplemental output signal, if required,
- 5.2.11 System operating characteristics, such as pressure and flow rate,
- 5.2.12 Materials,
- 5.2.13 Environmental requirements, such as vibration and ambient temperature,
- 5.2.14 Quantity of transducers required,
- 5.2.15 Size and weight restrictions (see 7.7),
- 5.2.16 Critical service life requirements (see 8.1),
- 5.2.17 Performance requirements (see 8.2),
- 5.2.18 Special surface finish requirements (see 9.1),
- 5.2.19 Special cleaning requirements (see 9.2),
- 5.2.20 When certification is required (see Section 13),
- 5.2.21 Special marking requirements (see Section 14),
- 5.2.22 Special packaging or package marking requirements (see Section 15),
- 5.2.23 When ISO 9001 quality assurance system is not required (see 16.1), and
- 5.2.24 Special warranty requirements (see 16.2).

6. **Materials and Manufacture**

6.1 *Sensing Elements*—The materials for the sensing element and wetted parts shall be selected for long-term compatibility (see 8.1) with the process medium (see 4.4).

7. **Physical Properties**

7.1 *Enclosure*—If case sealing is required, the mechanism, materials, and process shall be described. The same should apply to the electrical connector. The long-term resistance to common process media should be stated. Resistance to cleaning solvents should likewise be stated. Unique or special enclosure requirements shall be specified in the acquisition requirements (see 5.2).

7.2 *Transducer Mounting*—Transducers are commonly mounted directly by their pressure connections or through the use of brackets or similar hardware. Mounting force or torque shall be specified if it tends to affect transducer performance. Mounting error shall be specified in terms of percent of full-scale output or within the static error band under specified conditions of mounting force or torque.

7.3 *External Configuration*—The outline drawing shall show the configuration with dimensions in SI units (inch-pound units). The outline drawing shall include limiting dimensions for pressure and electrical connections if they are not specified. The outline drawing shall indicate the mounting method with hole size, center location, and other pertinent dimensions. Where threaded holes are used, thread specifications shall be provided.

7.4 *Standard Electrical Connection*—An electrical interface connector receptacle and mating plug shall be provided with each transducer unless otherwise specified in the contract (see 5.1). Optional possible electrical interface connections include pigtails and terminal boards.

7.5 *Pressure Connections*—Pressure connections commonly consist of pipe thread, hose tube fittings, O-ring union, O-ring union face seal, and others.

7.6 *Damping*—The use of a media for damping in transducers shall be specified including the type, composition, and compatibility with transducer components and materials.
7.7 Size and Weight—The purchaser may have intended applications in which size and weight are limited. Size and weight restrictions shall be specified in the ordering information (see 5.2).

8. Performance Requirements

8.1 Service Life—The purchaser may have a minimum specified service life requirement that may be critical. Critical service life requirements shall be specified in the ordering information (see 5.2).

8.2 Transducer Performance—Performance tolerances are usually specified in percent of transducer output span. Critical performance requirements shall be specified in the ordering information (see 5.2). The following performance characteristics and environmental exposures may or may not be important to each purchaser’s intended application: static error band, repeatability, hysteresis, sensitivity factor, ripple, warm-up time, steady-state supply voltage and frequency (ac), steady-state supply voltage (dc), response, transient supply voltage and frequency (ac), transient supply voltage (dc), temperature, humidity, overpressure, line pressure (differential only), salt spray, pressure cycling, insulation resistance, vibration, shock, burst pressure, output, enclosure, electromagnetic interference (EMI), common mode pressure (differential only), pressure rating (differential only), and power system harmonic distortion.

9. Workmanship, Finish and Appearance

9.1 Finish and Appearance—Any special surface finish and appearance requirements shall be specified in the ordering information (see 5.2).

9.2 Transducer Cleaning—Any special cleaning requirements shall be specified in the ordering information (see 5.2).

10. Number of Tests and Retests

10.1 Test Specimen—The number of test specimens to be subjected to first-article tests shall be specified and should depend on the transducer design. As guidance, if each range is covered by a separate and distinct design, a test specimen for each range should require testing. In instances in which a singular design series may cover multiple ranges and types, a minimum of three test specimens should be tested provided the singular design series may cover multiple ranges and types, a minimum of three test specimens should be tested provided the designer has identified that three units, one unit each representing the low, medium, and high ranges, be tested, regardless of design similarity.

10.1.1 Low Range—Less than 700 kPa (less than 100 lb/in.²).

10.1.2 Medium Range—700 kPa to less than 7 MPa (100 to less than 1000 lb/in.²).

10.1.3 High Range—7 MPa and greater (1000 lb/in.² and greater).

11. Test Methods

11.1 Test Data—All test data shall remain on file at the manufacturer’s facility for review by the purchaser upon request. It is recommended that test data be retained in the manufacturer’s files for at least three years, or a period of time acceptable to the purchaser and the manufacturer.

12. Inspection

12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

12.1.1 First-article tests (see 12.2).

12.1.2 Conformance tests (see 12.3).

12.2 First-Article Tests—First-article test requirements shall be specified, where applicable. First-article test methods should be identified for each design and performance characteristic specified. Test report documentation requirements should also be specified.

12.3 Conformance Tests—Conformance testing shall be specified when applicable. Conformance testing shall be conducted on all units manufactured for delivery unless otherwise specified in the contract.

13. Certification

13.1 When specified in the acquisition requirements (see 5.2), the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

14. Product Marking

14.1 The purchaser specified product marking shall be listed in the acquisition requirements (see 5.2). The minimum data to be clearly marked on each transducer shall include the following:

14.1.1 Manufacturer's name,

14.1.2 Manufacturer’s part number,

14.1.3 Serial number or lot number,

14.1.4 Date of manufacture,

14.1.5 Range,

14.1.6 Excitation voltage, and

14.1.7 Pressure rating (differential pressure transducers only).

14.2 For differential pressure transducers, the high- and low-pressure connections shall be clearly marked on the transducer body adjacent to the connections.

15. Packaging and Package Marking

15.1 Packaging of Product for Delivery—The product should be packaged for shipment in accordance with Practice D 3951.

15.2 Any special packaging or package marking requirements for shipment or storage shall be identified in the ordering information (see 5.2).

16. Quality Assurance

16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see 5.2).

16.2 Responsibility for Warranty—Unless otherwise specified, the manufacturer is responsible for the following:

16.2.1 All materials used to produce a unit and

16.2.2 Workmanship to produce the unit.

16.3 Special warranty requirements shall be specified in the acquisition requirements (see 5.2).
17. Keywords

17.1 differential pressure transmitter; fiber-optic pressure transducer; miniature; optoelectronics module; pressure and differential pressure transducers; pressure transmitter; sensing element; sensor head; transduction element

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement, established for U.S. naval shipboard application, shall apply when specified in the contract or purchase order. When there is conflict between this specification and this supplementary requirement, this supplementary requirement shall take precedence. This document supersedes MIL-T-24742, Transducer, Pressure and Differential Pressure, Miniature (Electrical), for new ship construction.

S1. TRANSDUCERS, PRESSURE AND DIFFERENTIAL PRESSURE, MINIATURE (ELECTRICAL)

S1.1 Scope

S1.1.1 This supplement covers the requirements for miniature pressure and differential pressure transducers designed to meet the requirements for use on board naval ships.

S1.1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in SI units.

S1.2 Referenced Documents

S1.2.1 ISO Standard:

6149-1 Connections for Fluid Power and General Use—Ports and Stud Ends with ISO 261 Threads and O-Ring Sealing—Part 1: Ports with O-Ring Seal in Truncated Housing

S1.2.2 NEMA Standard:

250 Enclosures for Electrical Equipment (1000 Volts Maximum)

S1.2.3 Military Standards:

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)

MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of

MIL-STD-1399, Section 300 Interface Standard for Shipboard Systems, Electric Power, Alternating Current

MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type

MS3456 Connector, Plug, Electrical, Rear Release, Crimp Contact, AN type

S1.3 Terminology

S1.3.1 Terminology is consistent with that of Section 3 and the referenced documents.

5 Available from National Electrical Manufacturers Association, 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
4—0-12 V
5—0-3 mV
6—0-200 µV

S1.4.7 Pressure Connection—Transducer pressure sensing connection shall be as follows:
N—M12 x 1.5 (7/16-20 UNF-2B) (see S1.7.5)
X—¼ nps, 155-mm (6-in.) long pipe nipple (see S1.7.5)
Z—Other

S1.4.8 Transducer Mounting—The transducer mounting method shall be designated as follows:
P—Pressure port connection
M—Mounting plate

S1.4.9 Range—The pressure range of the transducer shall be designated by two parts. The first part shall be the designator for the upper range value. The second part shall be the designator for the upper range unit of measure (see S1.4.9.1). The transducer pressure ranges shall be in accordance with Table S1.1.

S1.4.9.1 Units—The units shall be designated by the corresponding letter designator and are limited to the following:

<table>
<thead>
<tr>
<th>Letter</th>
<th>SI Units</th>
<th>Inch-Pound Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>kPaV—kiloPascals, vacuum</td>
<td>Hg—inches of mercury vacuum psi—pounds per square inch, absolute</td>
</tr>
<tr>
<td>A</td>
<td>kPaA—kiloPascals, absolute</td>
<td>psia—pounds per square inch, absolute</td>
</tr>
<tr>
<td>D</td>
<td>kPaD—kiloPascals, differential</td>
<td>psig—pounds per square inch, gage</td>
</tr>
<tr>
<td>G</td>
<td>kPaG—kiloPascals, gage</td>
<td>psig—pounds per square inch, gage</td>
</tr>
<tr>
<td>S</td>
<td>kPaS—kiloPascals, sealed at 101.4 kPaA</td>
<td>psig—pounds per square inch, sealed at 14.7 psia</td>
</tr>
<tr>
<td>W</td>
<td>kPaW—kiloPascals, water column</td>
<td>WC—inches of water column</td>
</tr>
<tr>
<td>N</td>
<td>kPaWD—kiloPascals, water column, differential</td>
<td>WCD—inches of water column, differential</td>
</tr>
</tbody>
</table>

S1.5 Ordering Information

S1.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data in accordance with S1.5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.

S1.5.2 Acquisition Requirements—Acquisition documents shall specify the following:
S1.5.2.1 Title, number, and date of this specification.
S1.5.2.2 Part designation.
S1.5.2.3 National Stock Number (NSN), if available.

<table>
<thead>
<tr>
<th>TABLE S1.1 Range</th>
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<tbody>
<tr>
<td>Type D</td>
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<tr>
<td>SI Units</td>
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<tr>
<td>Differential Pressure Ranges, kPaD</td>
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<tr>
<td>Range</td>
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<tr>
<td>0-100</td>
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<td>0-4000</td>
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<td>0-7000</td>
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</table>

<table>
<thead>
<tr>
<th>Inch-Pound Units</th>
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</thead>
<tbody>
<tr>
<td>Differential Pressure Ranges, psid</td>
</tr>
<tr>
<td>Range</td>
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<td>0-30</td>
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<td>0-1000</td>
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<tr>
<td>0-3000</td>
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<td>0-6000</td>
</tr>
</tbody>
</table>

<sup>A</sup>For upper range values of 7000 kPa (1000 lb/in.²) and above.
S1.5.2.4 Mounting method, if other than specified herein.
S1.5.2.5 Type of pressure connection, if other than specified herein.
S1.5.2.6 Type of electrical connection, if other than specified herein.
S1.5.2.7 When the electrical connection mating plug is not to be provided.
S1.5.2.8 Quantity of transducers required.
S1.5.2.9 If deviation requests are required when departing from material guidance.
S1.5.2.10 When first-article tests are required.
S1.5.2.11 Special product marking requirements.
S1.5.2.12 Special packaging or package marking requirements.
S1.5.2.13 When ISO 9001 quality assurance system is not required.
S1.5.2.14 Special warranty requirements.
S1.5.3 First-Article Tests—When first-article testing is required, the purchaser should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first-article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer’s current inventory. The number of items to be tested in accordance with S1.12.4 should be specified. The purchaser should include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article testing to those manufacturers offering a product that has been previously acquired or tested by the purchaser; and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S1.6 Materials
S1.6.1 Sensing Elements—The materials for the sensing element and wetted parts shall be selected for long-term compatibility (see S1.8.1) with the process medium (see S1.4.3). Table S1.2 is provided for guidance as acceptable material and process medium compatibility. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion. When departing from this guidance, the manufacturer shall provide evidence of material compatibility to the procuring activity, unless specified otherwise (see S1.5.1).

S1.7 Physical Properties
S1.7.1 Enclosure—The transducer body and pressure cavity shall be environmentally sealed unless otherwise specified. The transducer enclosure shall be Type 4 in accordance with NEMA Standard 250.
S1.7.2 Transducer Mounting—The transducer shall have a mounting plate as shown on Fig. S1.1. If required in a specific application and with prior approval of the purchaser, the transducer may be mounted by its pressure piping connection. For Type D transducers, the high-pressure port shall be used. If the transducer is mounted by its pressure connection, the mounting plate shall not be required (see S1.5.2). If the transducer is mounted by its pressure port connection and the mounting plate is provided, mounting holes shall not be required.

S1.7.3 External Configuration—The transducer shall have an external configuration within the boundaries established by Fig. S1.1.
S1.7.4 Electrical Connector—An electrical interface connector receptacle and mating plug shall be provided with each transducer unless otherwise specified. The electrical connector shall be a standard threaded coupling receptacle, AN type, MS3452W/14S-5P, or equivalent, for dc-power input, or AN type, MS3452W/14S-5PX, or equivalent, for ac-power input. The mating plug shall be a MS3456W/14S-5S, or equivalent, for dc-power input, or MS3456W/14S-5SX, or equivalent, for ac-power input.
S1.7.4.1 dc-Power Input—Output 2—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, and Pin C shall be case ground. Receptacle Pins A and B shall also serve as the 4- to 20-mA dc signal output.
S1.7.4.2 dc-Power Input—Output 3, 4, 5, 6—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, Pin C shall be case ground, Pin D shall be positive dc voltage signal output, and Pin E shall be negative dc voltage signal output.
S1.7.4.3 ac Power Input—Output 2—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be +4- to 20-mA dc-signal output, and Pin E shall be –4- to 20-mA dc signal output.
S1.7.4.4 ac Power Input—Output 3, 4, 5, 6—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be positive dc-voltage signal output, and Pin E shall be negative dc voltage signal output.
S1.7.5 Pressure Connections—Unless otherwise specified, transducer pressure-sensing connections for all services shall
be M12 × 1.5 (3/4-20 UNF-2B) tube connection in accordance with ISO 6149-1. When pressure connection Type X is specified, as commonly used on submarine oxygen replenishment systems, the transducer sensing connections shall be a nickel-copper pipe nipple 1/4 nominal pipe size (nps) with 3.1-mm (0.12-in.) minimum wall thickness, 155 mm (6 in.) long, welded to the socket (see S1.5.2). For Type D transducers, the high-pressure connection shall be on the end and the low-pressure connection shall be on the side (see Fig. S1.1).

S1.7.6 Welding—For Application X, all pressure boundary joints shall be welded.

S1.7.7 Lubrication—The transducer shall operate without lubrication of moving parts after assembly.

S1.7.8 Damping—The use of a media for damping in transducers shall be cited on the equipment drawing.

S1.7.9 Weight—The weight of a transducer shall not exceed 510 g (18 oz).

S1.8 Performance Requirements

S1.8.1 Service Life—The transducer shall be constructed for a life of 40 000 h of operation and shall meet the requirements specified herein when operated in the naval shipboard environment.

S1.8.2 Input Power—The transducer shall be designed to operate using 115-V, 60-Hz, single-phase, ungrounded, ac power as defined in MIL-STD-1399, Section 300 or 28 ± 4.5-Vdc power. The transducer shall operate with power supply variations as specified in S1.11.2.8 and S1.11.2.11.

S1.8.3 Output—The electrical signal output of the transducer shall be dc, directly proportional to the pressure or differential pressure input. The output shall be a true current source or true voltage source.

S1.8.3.1 Current Output—When a 4- to 20-mA current output is specified (see S1.5.2), the requirements specified herein shall be met regardless of external load resistance variations over a range from 0 to 250 Ω. The 4-mA output shall correspond to the lower pressure or differential pressure range value, and the 20-mA output shall correspond to the upper pressure or differential pressure range value for the ranges specified in Table S1.1.

S1.8.3.2 Voltage Output—When a voltage output is specified (see S1.5.2), the requirements specified herein shall be met for external load resistance exceeding 100 000 Ω. The 0-V output shall correspond to the lower pressure or differential pressure range value, and the 5-V, 12-V, 3-mV, and 200-µV output shall correspond to the upper pressure or differential pressure range value for the ranges specified in Table S1.1.

S1.8.4 Transducer Performance—Unless otherwise specified, performance tolerances are specified in percent of transducer output span.

S1.8.4.1 Static Error Band—The transducer static error band shall not exceed ±0.5 %.

S1.8.4.2 Output—The output shall conform to S1.8.3, and the transducer performance shall be within the static error band specified in S1.8.4.1.
S1.8.4.3 Warm-Up Time—The transducer output shall attain a value within ±0.5 % of the steady-state output with no overshoot in excess of 0.5 %. Output shall reach this band within 15 s after the transducer is energized and shall remain in this band.

S1.8.4.4 Enclosure—The transducer shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S1.8.4.5 Repeatability—Repeatability of the transducer output shall be within 0.5 %.

S1.8.4.6 Sensitivity Factor—The sensitivity factor shall not be less than 0.75 nor more than 1.25.

S1.8.4.7 Ripple—The transducer root mean square (rms) output ripple shall not exceed 0.15 % of full-scale dc output.

S1.8.4.8 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The maximum difference between outputs at any voltage and frequency or voltage (for dc) condition and the normal (115-V, 60-Hz, or 28-Vdc) at the same input and test temperature (differential pressure shall be included for Type D) shall not exceed 0.5 %.

S1.8.4.9 Common Mode Pressure (Type D Only)—During the common mode pressure test, transducer performance shall be within the range formed by extending the upper and lower static error band limits specified in S1.8.4.1 by a percentage equal to the following:

\[
\frac{1}{10} \text{system pressure rating} \times \frac{1}{10} \text{differential pressure range}
\]

S1.8.4.10 Response—Transducer output shall conform to the following criteria, where all percentages are of transducer span:

1. The transducer output shall be within ±2 % of the maximum ramp pressure within 0.01 s of the time that pressure is attained.
2. The transducer output shall exhibit no overshoot of maximum ramp pressure in excess of 2 %.
3. The transducer output shall indicate the actual pressure to within ±1 % in 0.175 s or less after attainment of the maximum ramp pressure, and shall remain within this error band for the duration of the applied steady-state pressure.

S1.8.4.11 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc):

1. Voltage—During the transient test, the transducer output shall remain within ±0.5 % of the pretransient output.
2. Frequency—During the frequency transient test, the transducer output shall remain within ±0.5 % of the steady-state output.

S1.8.4.12 Temperature—During the temperature test, the transducer performance shall be within the static error band specified in S1.8.4.1.

S1.8.4.13 Overpressure—The calibration conducted after the overpressure test shall have no values in excess of 1 % deviation from the pre-overpressure test reference measurement.

S1.8.4.14 Line Pressure (Type D Only)—After the line pressure test, the transducer performance shall be within the static error band specified in S1.8.4.1.

S1.8.4.15 Pressure Cycling—The calibration conducted after completion of pressure cycling test shall have no values in excess of 1 % deviation from pretest reference measurement.

S1.8.4.16 Insulation Resistance—The insulation resistance of the transducer shall be not less than 10 MΩ.

S1.8.4.17 Vibration—Monitored transducer output during all phases of vibration test shall show no variation from steady-state output in excess of 2 %. There shall be no visible evidence of damage to the transducer as a result of the vibration test.

S1.8.4.18 Shock—The transducer shall operate during and after the shock test. After the shock test, the transducer output shall have no value in excess of 1 % deviation from the preshock test reference measurement. There shall be no visual evidence of damage to the transducer as a result of the shock test.

S1.8.4.19 Burst Pressure—The transducer shall withstand the burst pressure specified in S1.11.2.19 without showing any evidence of leakage.

S1.8.4.20 Electromagnetic Interference (EMI)—The transducers shall meet the requirements of Table II of MIL-STD-461, except as modified as follows:

1. CE101—The test signal shall be applied only to the ac power leads of the test sample.
2. CE102—The test signal shall be applied only to the ac power leads of the test sample.
3. CS114—Only Limit Curve #2 shall apply with the frequency range limited from 10 kHz to 30 MHz.
4. RE101—Only the limit curve for 50 cm shall apply.
5. RS103—The frequency range shall be limited from 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

S1.9 Workmanship, Finish, and Appearance

S1.9.1 Transducer Cleaning—The manufacturer shall ensure that pressure transducers shall be free of all loose scale, rust, grit, filings, and other foreign substances and free of mercury, oil, grease, or other organic materials. In addition, the following shall apply:

1. Transducers for oxygen service, Application X (see S1.4.3), shall be clean gas calibrated, cleaned, and pressure connections capped.
2. Transducers for all other applications shall be freshwater or clean gas calibrated, cleaned, and pressure connections capped.

S1.10 Number of Tests and Retests

S1.10.1 The number of test specimens to be subjected to first-article and conformance tests shall depend on the transducer design. If each range is covered by a separate and distinct design, a test specimen for each range shall require testing. In instances in which a singular design series may cover multiple ranges and types, only three test specimens need be tested provided the electrical and mechanical similarities are approved by the purchaser. In no case, however, shall less than three units, one unit each representing the low, medium, and high ranges, be tested, regardless of design similarity.

S1.10.1.1 Low Range—Less than 700 kPa (less than 100 lb/in.²).
S1.10.1.2 Medium Range—700 kPa to less than 7 MPa (100 to less than 1000 lb/in.²).
S1.10.1.3 High Range—7 MPa and greater (1000 lb/in.² and greater).
S1.11 Test Methods

S1.11.1 Test Conditions—Except where the following factors are the variables, the tests specified in S1.11.2 shall be conducted with the equipment under the following operating environmental conditions:

S1.11.1.1 Ambient temperature shall be 23 ± 2°C.
S1.11.1.2 Relative humidity shall be ambient.
S1.11.2 Tests—Except for the warm-up time test (see S1.11.2.3), the transducer and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S1.11.2.1 Reference Measurement—A reference measurement consisting of one-trial calibration with at least five equally spaced intervals over the entire transducer range both upscale and downscale shall be conducted when specified in the individual test.

S1.11.2.2 Output—A reference measurement shall be made in accordance with S1.11.2.1. Performance shall conform to the requirements of S1.8.4.2.

S1.11.2.3 Warm-Up Time—The test shall be conducted to determine the elapsed time between the application of line power to the transducer and the point at which the transducer output reaches the conditions specified in S1.8.4.3.

S1.11.2.3.1 Test Conditions—The transducer shall be subjected to the ambient temperature of the testing location, while deenergized, for not less than 2 h. Recording equipment and other auxiliary equipment shall be energized to ensure complete warm-up. An input pressure (differential pressure for Type D) of 80 ± 5 % of the transducer span shall be applied to the transducer and maintained constant during this test. Performance shall conform to S1.8.4.

S1.11.2.4 Enclosure—The enclosure shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. Performance shall conform to S1.8.4.4.

S1.11.2.5 Static Error Band and Repeatability—The transducer shall first be flexed over its full-pressure range by slowly increasing and decreasing the applied pressure for six continuous cycles. The calibration measurement shall be made at a minimum of five equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error band of all calibrations shall meet the requirements of S1.8.4.1. Repeatability shall meet the requirements of S1.8.4.5.

S1.11.2.6 Sensitivity Factor—The sensitivity factor shall be determined as follows: Provide a pressure (differential pressure for Type D) to the transducer to a level of 80 ± 5 % of span. Record the input pressure (differential pressure) and corresponding electrical output. Increase the pressure (differential pressure) by an amount not exceeding 1 % of span. Record both the new pressure (differential pressure) and corresponding new electrical output. Calculate the change in both applied pressure (differential pressure) and electrical output as a percentage of transducer span. Determine the ratio of electrical output percentage change to applied pressure (differential pressure) percent change. Repeat this procedure for a pressure (differential pressure) decrease not exceeding 1 % of span. Performance shall conform to the requirements of S1.8.4.6.

S1.11.2.7 Ripple—Transducer output root mean square ripple shall be determined at an input pressure (differential pressure for Type D) of 80 ± 5 % of transducer span. Performance shall conform to the requirements of S1.8.4.7.

S1.11.2.8 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The transducer shall be operated at normal, maximum, and minimum steady-state voltages (dc) and at all possible combinations of normal, maximum, and minimum voltages and frequencies (ac). The ambient temperature shall also vary, with the transducer operated for at least 15 min at each test temperature before the first reference measurement. The transducer shall be allowed at least 15 min to stabilize at each configuration at which point a reference measurement shall be taken (see S1.11.2.1). Reference measurements shall be performed at ambient temperatures of 0 ± 2, 25 ± 2, and 65 ± 2°C. Test temperatures shall be accomplished by varying temperature in steps of 10°C each (30 min for each step) until the desired ambient temperature is reached. Performance shall conform to S1.8.4.8.

S1.11.2.9 Common Mode Pressure (Transducer Type D Only)—The rated pressure of the transducer shall be applied simultaneously to both pressure ports. The pressure at the low-pressure port shall then be decreased in pressure increments specified in S1.11.2.1 to the specified transducer range and then increased in similar increments to the transducer-rated pressure. Performance shall conform to S1.8.4.9.

S1.11.2.10 Response—A pressure (differential pressure for Type D) ramp consisting of a pressure (differential pressure for Type D) rise of at least 40 % of transducer span occurring at a rate of not less than 400 %/s shall be applied to the transducer operating at the upper and lower limits of steady-state frequency, a transient voltage of no more than ±16 %, recovering to the steady-state band in 2 s, superimposed. With the transducer operating at the upper and lower limits of steady-state ac voltage, the ac-powered transducer shall have a transient voltage of no more than ±16 %, recovering to the steady-state band in 2 s, superimposed. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of no more than ±2 V, respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S1.8.4.11.

I) Transient Voltage:

(a) Upper and Lower Limits of Steady-State Voltage—With the transducer operating at the upper and lower limits of steady-state ac voltage, the ac-powered transducer shall have a transient voltage of no more than ±16 %, recovering to the steady-state band in 2 s, superimposed. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of no more than ±2 V, respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S1.8.4.11.

(b) Lower Limit of Steady-State Frequency—With the transducer operating at the lower limit of steady-state frequency, a transient frequency of +1.5 Hz recovering to the steady-state
band in 2 s shall be superimposed. Performance shall conform to the requirements of S1.8.4.11.

S1.11.2.12 Temperature—The transducer shall operate normally (without alignment or adjustment) throughout the following temperature cycle. Tolerances in operating characteristics shall be as specified herein.

1. Hold the test temperature at 0 ± 2°C for at least 24 h.
2. Increase the test temperature in steps of 5°C each, at 30 min for each step, until +65 ± 2°C is reached and hold at that temperature for at least 4 h.
3. Reduce the test temperature in steps of 5°C each, at 30 min for each step, until +25 ± 2°C is reached and hold at that temperature for at least 4 h. At each temperature plateau (0, 65, and 25°C), a reference measurement (see S1.11.2.1) shall be made. Performance shall conform to S1.8.4.12.

S1.11.2.13 Overpressure—Before the overpressure test, a reference measurement in accordance with S1.11.2.1 shall be made. The transducer shall successfully withstand pressure (differential pressure for Type D) equal to 200 % of its range with a maximum pressure of 85 MPa (12 000 lb/in.²) for a period of ½ h. At the end of this period, transducers shall be immediately subjected to a pressure equal to 7 kPa (1 lb/in.²) or 10 % of range, whichever is less, below atmospheric for an additional period of ½ h. Within 10 min after release of this pressure, a reference measurement (see S1.11.2.1) shall be made for comparison. Performance shall conform to S1.8.4.13.

For Type D only, if the line pressure rating exceeds 200 % of the differential pressure range, the overpressure test shall be omitted and 0.5 % deviation shall be applied to the line pressure test (see S1.11.2.14).

S1.11.2.14 Line Pressure (for Type D Only)—The transducer shall successfully withstand the pressure rating, when applied to the high-pressure port with the low-pressure port vented to atmosphere for a period of 10 min. The preceding shall be repeated with the pressure applied to the low-pressure port of the transducer. After each test, a reference measurement in accordance with S1.11.2.1 shall be made. Performance shall conform to S1.8.4.14.

S1.11.2.15 Pressure Cycling—Before performing the pressure cycling test, a reference measurement shall be made (see S1.11.2.1). The test shall be conducted on a suitable system by applying a periodic pressure change of not more than 20 % to not less than 80 % of span for a total of 260 000 cycles. The rate of cycling shall be within the range from 0.25 to 2 Hz. The transducer shall be energized throughout the test. After completion of the pressure cycling test, a reference measurement shall be made for comparison (see S1.11.2.1). Performance shall conform to S1.8.4.15.

S1.11.2.16 Insulation Resistance—The insulation resistance of the transducer shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The relative humidity shall be 50 ± 10 %. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance meets the specified limit (see S1.8.4.16) and is steady or increasing, the test may be terminated before the end of the 2-min period.
test which may be conducted on separate transducers, the test specimens (transducers) shall be subjected to the tests specified in Table S1.4 in the order listed. Deviation of the test order shall be approved by the purchaser.

S1.12.3 Conformance Tests—Each pressure transducer in each lot offered for delivery shall be subjected to the tests listed in Table S1.5 and shall be conducted in the order listed. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S1.12.4 General Examination—Each transducer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with applicable approved industry standards.

S1.13 Certification

S1.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer’s facility for review by the purchaser upon request.

S1.14 Product Marking

<table>
<thead>
<tr>
<th>TABLE S1.4 First-Article Tests</th>
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<tbody>
<tr>
<td>Test</td>
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<tr>
<td>Output</td>
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<tr>
<td>Warm-up time</td>
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<tr>
<td>Enclosure</td>
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<tr>
<td>Static error band and repeatability</td>
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<tr>
<td>Sensitivity factor</td>
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<tr>
<td>Ripple</td>
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<tr>
<td>Supply voltage and frequency (steady-state)</td>
</tr>
<tr>
<td>Common mode pressure (transducer Type D only)</td>
</tr>
<tr>
<td>Response</td>
</tr>
<tr>
<td>Supply voltage and frequency (transient)</td>
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<tr>
<td>Temperature</td>
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<tr>
<td>Overpressure</td>
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<tr>
<td>Line pressure (transducer Type D only)</td>
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<tr>
<td>Pressure cycling</td>
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<tr>
<td>Insulation resistance</td>
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<tr>
<td>Vibration</td>
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<tr>
<td>Shock</td>
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<tr>
<td>Burst pressure</td>
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</tbody>
</table>

S1.14.1 Label Plates—A label plate with engraved or stamped markings shall be permanently affixed to the transducer. At a minimum, it shall contain the following: S1.14.1.1 "PRESSURE TRANSDUCER" or "DIFFERENTIAL PRESSURE TRANSDUCER."

S1.14.1.2 Manufacturer’s name,
S1.14.1.3 National Stock Number (NSN), if available,
S1.14.1.4 Date of manufacture,
S1.14.1.5 Designation, and
S1.14.1.6 Pressure rating for Type D transducers.
S1.14.2 Transducers for use with Applications F and X (see S1.4.3) shall have “USE NO OIL FOR CALIBRATION” prominently marked on the body.

S1.14.3 For Type D transducers, the high- and low-pressure connections shall be clearly marked on the transducer body adjacent to the connections.

S1.14.4 The legend "DO NOT LUBRicate" shall be prominently marked on the body.

S1.15 Packaging and Package Marking

S1.15.1 Packaging and package marking shall be in accordance with Section 15.

S1.16 Quality Assurance

S1.16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see S1.5.2).

S1.16.2 Warranty—Any special warranty requirements shall be specified in the acquisition requirements (see S1.5.2). The following supplementary requirement, established for U.S. naval shipboard application, shall apply when specified in the contract or purchase order. When there is conflict between this specification and this supplementary requirement, this supplementary requirement shall take precedence. This document supersedes MIL-S-24796, Sensors, Absolute Pressure, Fiber Optic (Naval Shipboard Use), for new ship construction.

S2. TRANSDUCERS, PRESSURE AND DIFFERENTIAL PRESSURE, FIBER-OPTIC

S2.1 Scope

S2.1.1 This supplement covers the requirements for fiber-optic pressure transducers designed to meet the requirements for use onboard naval ships.

S2.1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in SI units.

S2.2 Referenced Documents

S2.2.1 ASTM Standards:
D 542 Test Methods for Index of Refraction of Transparent Organic Plastics
D 570 Test Method for Water Absorption of Plastics
S2.2.2 EIA Standard:
TIA-422 Electrical Characteristics of Balanced Voltage Digital Interface Circuits

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7 Annual Book of ASTM Standards, Vol 08.01.
S2.2.3 ISO Standard:
6149-1 Connections for Fluid Power and General Use—Ports and Stud Ends with ISO 261 Threads and O-Ring Sealing—Part 1: Port with O-Ring Seal in Truncated Housing

S2.2.4 NEMA Standard:
250 Enclosures for Electrical Equipment (1000 Volts Maximum)

S2.2.5 Military Standards:
MIL-PRF-49291 Fiber, Optical (Metric), General Specification for
MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)
MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of
MIL-STD-1399, Section 300 Interface Standard for Shipboard Systems, Electric Power, Alternating Current
MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type
MS3456 Connector, Plug, Electrical, Rear Release, Crimp Contact, AN Type

S2.3 Terminology
S2.3.1 Terminology is consistent with that of Section 3 and the referenced documents.

S2.4 Classification
S2.4.1 Designation—For this specification, fiber-optic pressure transducer designations shall be assigned in accordance with S2.5.1 and listed in the following format:

Example: F25FXMS2-P-F-X-AC-A-N-1-P-100A

S2.4.2 Type—The following designators have been established for the various types of fiber-optic transducers:
D—Pressure, differential
P—Pressure (gage, sealed, absolute)
V—Pressure, vacuum
C—Pressure, compound

S2.4.3 Application—The following application designations have been established for the media to be measured:
F—Freshwater, oil, condensate, steam, nitrogen, and other inert gases
S—Seawater
G—Flue gas and ammonia
X—Oxygen

S2.4.4 Pressure Rating—The pressure rating shall be indicated by the designator for its numerical value for Type D transducers ("X" for Type P, V, and C transducers) and shall be limited to the following:

<table>
<thead>
<tr>
<th>Designator</th>
<th>Rating, kPaG</th>
<th>Inch-Pound Units, psig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>150</td>
</tr>
</tbody>
</table>

S2.4.5 Power Supply—Transducers shall operate with either ac or dc input power, but not both. Designators shall be as follows:
S2.4.5.1 dc—Direct current supply.
S2.4.5.2 ac—Alternating current supply.
S2.4.6 Output—The prime output shall be an electrical dc signal. A supplemental output shall also be provided when specified. The signal output of the transducer shall be designated by the following designators:
A—4 to 20 mA
V—0 to 5 V
O—Optical (and current)
D—Digital (and current)

S2.4.7 Pressure Connection—Transducer pressure sensing connection shall be as follows:
N—M12 × 1.5 (1/4-20 UNF-2B) (see S7.5)
X—1/4 nps, 155-mm (6-in.) long pipe nipple (see S7.5)
Z—Other

S2.4.8 Optoelectronics Module—The optoelectronics module shall be designated as follows:
1—Bulkhead mounted
2—Console mounted

S2.4.9 Transducer Mounting—The transducer mounting method shall be designated as follows:
P—Pressure port connection
M—Mounting plate

S2.4.10 Range—The pressure range of the transducer shall be designated by two parts. The first part shall be the designator for the upper range value. The second part shall be the designator for the upper range unit of measure (see S2.4.8.1). The transducer pressure ranges shall be in accordance with Table S2.1.

S2.4.10.1 Units—The units shall be designated by the corresponding letter designator and are limited to the following:

<table>
<thead>
<tr>
<th>Letter</th>
<th>SI Units</th>
<th>Inch-Pound Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>kPaV</td>
<td>Hg— inches of mercury vacuum</td>
</tr>
<tr>
<td>A</td>
<td>kPaA</td>
<td>psia— pounds per square inch, absolute</td>
</tr>
<tr>
<td>D</td>
<td>kPaD</td>
<td>psd— pounds per square inch, differential</td>
</tr>
<tr>
<td>G</td>
<td>kPaG</td>
<td>psig— pounds per square inch, gauge</td>
</tr>
<tr>
<td>S</td>
<td>kPaS</td>
<td>psi— pounds per square inch, sealed at 14.7 psia</td>
</tr>
<tr>
<td>W</td>
<td>kPaW</td>
<td>kPaW—kPaWs, water column</td>
</tr>
<tr>
<td>N</td>
<td>kPaWD</td>
<td>WC— inches of water column, differential</td>
</tr>
</tbody>
</table>

S2.5 Ordering Information
S2.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data in accordance with S2.5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.

S2.5.2 Acquisition Requirements—Acquisition documents shall specify the following:
S2.5.2.1 Title, number, and date of this specification.
S2.5.2.2 Part designation required (see S2.4.1).
S2.5.2.3 National Stock Number (NSN), if available.
S2.5.2.4 Transducer mounting method, if other than specified herein (see S2.7.2).
S2.5.2.5 Optoelectronics module mounting method, if other than specified herein (see S2.7.2).
S2.5.2.6 Type of pressure connection, if other than specified herein (see S2.7.7).
S2.5.2.7 Type of electrical connection, if other than specified herein (see S2.7.6).
S2.5.2.8 When the electrical connection mating plug is not to be provided (see S2.7.6).
S2.5.2.9 Requirements when Type 2 optoelectronics module is specified (see S2.7.2).
S2.5.2.10 Fiber-optic cable length required (see S2.7.3).
S2.5.2.11 Output requirements when Type O output is specified (see S2.8.3.3) or output requirements and data format when Type D output is specified (see S2.8.3.4).
S2.5.2.12 Electrical connectors when Type D output is specified (see S2.7.6).
S2.5.2.13 When overload protection is required for the optoelectronics module (see S2.7.9).
S2.5.2.14 Quantity of transducers required.
S2.5.2.15 When first-article tests are required (see S2.12.3).
S2.5.2.16 Group B inspection sample size (see S2.12.3.2).
S2.5.2.17 Special product marking requirements (see S2.14).
S2.5.2.18 Special packaging or package marking requirements (see S2.15).
S2.5.2.19 When ISO 9001 quality assurance system is not required (see S2.16.1).
S2.5.2.20 Special warranty requirements (see S2.16.2).

First-Article Tests—When first-article tests are required, the purchaser should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first-article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer’s current inventory. The number of items to be tested in accordance with S2.12.4 should be specified. The purchaser should also include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article testing to those manufacturers offering a product that has been previously

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TABLE S2.1 Range

<table>
<thead>
<tr>
<th>Differential Pressure Ranges, kPaD</th>
<th>Differential Pressure Water Column Ranges, kPaWD</th>
<th>Pressure Ranges, kPaG, kPaP, or kPaS</th>
<th>Water Column Ranges, kPaW</th>
<th>Compound Ranges, kPaV/kPaG</th>
<th>Vacuum Range, kPaV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range Designator</td>
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Inch-Pound Units

<table>
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<tr>
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<th>Differential Pressure Water Column Ranges, WCD</th>
<th>Pressure Ranges, psig, psia, or psis</th>
<th>Water Column Ranges, WC</th>
<th>Compound Ranges, Hg-0-psig</th>
<th>Vacuum Range, Hg</th>
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<td>1250</td>
<td>0-400</td>
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</tbody>
</table>

For upper range values of 7000 kPa (1000 lb/in.²) and above.
acquired or tested by the purchaser, and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S2.6 Materials

S2.6.1 Metals—Unless otherwise specified herein, all metals used in the construction of the transducer shall be corrosion resistant. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion. The materials for the wetted parts shall be selected for long-term compatibility with the process medium.

S2.6.2 Flammable Materials—Materials used in the construction of the transducer shall in the end configuration be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application. Fire retardance shall not be achieved by use of nonpermanent additives to the basic material.

S2.6.3 Fungus-Resistant Materials—Materials used in the construction of the transducer shall not support the growth of fungus.

S2.6.4 Solvents, Adhesives, and Cleaning Agents—When chemicals or cements are used in bonding of internal transducer components, no degradation shall result during in-service use.

S2.6.5 Refractive Index Matching Gels, Fluids, or Compounds—Refractive index matching gels, fluids, or compounds shall not produce toxic, corrosive, or explosive by-products. The material is subject to a toxicological data and formulations review and inspection, for safety of material, by the purchaser. The index matching material shall be either silicone or aliphatic hydrocarbon material and shall be clear and transparent. The index matching material shall have an index of refraction of $1.46 \pm 0.01$ as tested in accordance with Test Methods D 542, when exposed to operating temperature extremes between $-28$ and $+85^\circ$C. The index matching material shall not flow at elevated temperatures. The index matching material shall remain clear and transparent when tested for water absorption in accordance with Test Method D 570. The index matching material shall have a shelf life not less than 36 months at $25 \pm 5^\circ$C. The 36-month period commences on the date of adhesive manufacture.

S2.7 Physical Properties

S2.7.1 Sensor Head Configuration—The sensor head shall be constructed in accordance with configuration limits in Fig. S2.1. When required for repair or maintenance, replacement of sensor head components shall be accomplished with the sensor head body remaining fixed in place at mounting plate and pressure connection points.

S2.7.1.1 Sensor Head Mounting—The sensor head shall be mounted using mounting holes in locations shown in Fig. S2.1. If required in a specific application and with prior approval of the purchaser, the sensor head may be mounted by its pressure piping connection (see S2.5.2). For Type D transducers, the high-pressure port shall be used. If the sensor head is mounted

<table>
<thead>
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<th>Dimension</th>
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<th>in.</th>
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</thead>
<tbody>
<tr>
<td>A</td>
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</tr>
<tr>
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<tr>
<td>C</td>
<td>6.5 max</td>
<td>0.25 max</td>
</tr>
<tr>
<td>D</td>
<td>$76.0 \leq F \leq 101.0$</td>
<td>$3.0 \leq F \leq 4.0$</td>
</tr>
<tr>
<td>E</td>
<td>63.5</td>
<td>2.5</td>
</tr>
<tr>
<td>F</td>
<td>$19.0 \leq F \leq 25.0$</td>
<td>$0.75 \leq F \leq 1.0$</td>
</tr>
<tr>
<td>G</td>
<td>72.0</td>
<td>2.83</td>
</tr>
<tr>
<td>H</td>
<td>$7.2 \pm 0.15$</td>
<td>$0.281 \pm 0.005$</td>
</tr>
</tbody>
</table>

Note 1—Sensor head housing (body) cross section is shown as circular. Any alternate cross section not exceeding 50 mm (2 in.) in width and 50 mm (2 in.) in height is acceptable.

Note 2—Dimension tolerance is plus or minus 1.25 mm (0.05 in.), unless otherwise specified.

Note 3—The pressure connection(s) shall be generally located as shown.

FIG. S2.1 Sensor Head External Configuration
by its pressure connection, mounting holes shall not be required. It is recommended that the sensor head be installed such that sufficient clearance is provided for repair and maintenance of the unit.

S2.7.2 Optoelectronics Module—The optoelectronics module shall contain the optical and signal conditioners needed to convert the sensor head output to the specified transducer output signal. Access to the interior of the optoelectronics module shall be possible to replace the connectorized cable. The module shall be bulkhead mounted or console mounted as specified in acquisition requirements (see S2.5.2).

S2.7.2.1 Bulkhead Mounted (Type 1)—The optoelectronics module shall be housed in a NEMA Standard 250 Type 4 enclosure.

S2.7.2.2 Console Mounted (Type 2)—The optoelectronics module shall be packaged in a console-mounted circuit card as specified in acquisition requirements (see S2.5.2).

S2.7.2.3 Fiber-Optic Cable—A fiber-optic cable shall be used to connect the sensor head to the optoelectronics module. There shall be no less than two times the number of fibers needed for operation of the transducer in the cable. Penetration of the fiber-optic cable into both the sensor head and the optoelectronics module shall be watertight. The required length of cable shall be as specified in acquisition requirements (see S2.5.2).

S2.7.4 Optical Fiber—All optical fiber used in the construction of the transducer shall be in accordance with MIL-PRF-49291.

S2.7.5 Fiber-Optic Connectors, Receptacles, and Bulkhead Adapters—All fiber-optic connectors, receptacles, and bulkhead adaptors shall be in accordance with MIL-C-83522 and MIL-C-83522/16, 17, and 18, respectively, or equivalent. Connectors shall be assembled at both ends of the fiber-optic cable between the sensor head and the optoelectronics module. The connectors and receptacles shall be mounted inside the sensor head and optoelectronics module.

S2.7.6 Electrical Connector—An electrical interface connector receptacle and mating plug shall be provided with each optoelectronics module of the transducer unless otherwise specified. The electrical connector shall be a standard threaded coupling receptacle, AN type, MS3452W/14S-5P, or equivalent, for dc-power input, or AN type, MS3452W/14S-5PX, or equivalent, for ac-power input. The mating plug shall be a MS3456W/14S-5S, or equivalent, for dc-power input, or MS3456W/14S-5SX, or equivalent, for ac-power input. Electrical connectors for digital output shall be as specified (see S2.5.2).

S2.7.6.1 dc-Power Input—Current Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, and Pin C shall be case ground. Receptacle Pins A and B shall also serve as the 4-20-mA dc signal output.

S2.7.6.2 dc-Power Input—Voltage Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, Pin C shall be case ground, Pin D shall be +0-5-Vdc signal output, and Pin E shall be –0-5-Vdc signal output.

S2.7.6.3 ac-Power Input—Current Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input. Pin C shall be case ground, Pin D shall be +4-20-mA dc signal output, and Pin E shall be –4-20-mA dc signal output.

S2.7.6.4 ac-Power Input—Voltage Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be +0-5-Vdc signal output, and Pin E shall be –0-5-Vdc signal output.

S2.7.7 Pressure Connections—Unless otherwise specified, transducer pressure-sensing connections for all services shall be M12 × 1.5 (7/32 UNF-2B) tube connection in accordance with ISO 6149-1. When pressure connection Type X is specified, as commonly used on submarine oxygen replenishment systems, the transducer sensing connections shall be a nickel-copper pipe nipple ¼ nominal pipe size (nps) with 3.1-mm (0.12-in.) minimum wall thickness, 155 mm (6 in.) long, welded to the socket (see S2.5.2). For Type D transducers, the high-pressure connection shall be on the end and the low-pressure connection shall be on the side (see Fig. S2.1).

S2.7.8 Adjustments—Tamper-proof adjustments for zero and span may be provided on the optoelectronics module for calibration purposes. The number of adjustments shall be kept to a minimum consistent with the operation and maintenance requirements. Electrical disconnection shall not be required to accomplish these adjustments.

S2.7.9 Electrical Overload Protection and Isolation—The optoelectronics module shall be provided with overload protection when not adequately protected by the ship’s power circuits (see S2.5.2). A means of isolating the optoelectronics module from ship power shall be provided on the unit.

S2.7.10 Calibration Media—Oil shall not be used as the calibration media.

S2.7.11 Welding—For Application X, all pressure boundary joints shall be welded.

S2.7.12 Lubrication—The transducer shall not require lubrication.

S2.7.13 Damping—The use of oil for damping is prohibited.

S2.7.14 Weight—The weight of the sensor head shall not exceed 510 g (18 oz). The weight of the optoelectronics module shall not exceed 4.5 kg (10 lb).

S2.8 Performance Requirements

S2.8.1 Service Life—The transducer shall be constructed for a service life of no less than 40 000 h and shall meet the requirements specified herein when operated in the naval shipboard environment.

S2.8.2 Input Power—The transducer shall be designed to operate using 115-V, 60-Hz, single-phase, ungrounded, ac power as defined in MIL-STD-1399, Section 300 or 28 ± 4.5-V dc power. The transducer shall operate with power supply variations as specified in S2.11.2.7 and S2.11.2.8.

S2.8.3 Output—The prime transducer output shall be an electrical dc signal that is directly proportional to the input
pressure and shall be a true current or voltage source. If an optical or digital output is required, it shall be a supplemental output.

S2.8.3.1 Current Output—When a 4- to 20-mA current output is specified (see S2.5.2), the requirements specified herein shall be met regardless of external load resistance variations over a range from 0 to 250 $\Omega$. The output shall be directly proportional to the input pressure. The 4-mA output shall correspond to the lower pressure range value and the 20-mA output shall correspond to the upper pressure range value for the ranges specified in Table S2.1.

S2.8.3.2 Voltage Output—When a 0- to 5-V output is specified (see S2.5.2), the requirements specified herein shall be met for external load resistance exceeding 100 000 $\Omega$. The output shall be directly proportional to the input pressure. The 0-V output shall correspond to the lower pressure range value, and the 5-V output shall correspond to the upper pressure range value for the ranges specified in Table S2.1.

S2.8.3.3 Optical Output—When an optical output is specified (see S2.5.2), the optical output requirements shall be as specified in the ordering data (see S2.5.2).

S2.8.3.4 Digital Output—When an electrical digital output is specified (see S2.5.2), the digital output requirements shall be as specified in the ordering data (see S2.5.2). The electrical characteristics shall be in accordance with EIA Standard TIA-422 for balanced voltage digital interface circuitry, or as specified (see S2.5.2). The data format shall be as specified (see S2.5.2).

S2.8.4 Transducer Performance—Unless otherwise specified, performance tolerances are specified in percent of transducer output span.

S2.8.4.1 Static Error Band—The transducer static error band shall not exceed $\pm 1\%$.

S2.8.4.2 Repeatability—Repeatability of the transducer output shall be within $0.5\%$.

S2.8.4.3 Sensitivity Factor—The sensitivity factor shall not be less than 0.75 nor more than 1.25.

S2.8.4.4 Response—The transducer output shall conform to the following criteria, where all percentages are of transducer span:

1. The transducer output shall be within $\pm 2\%$ of the maximum ramp pressure within 0.01 s of the time that pressure is attained.

2. The transducer output shall exhibit no overshoot of maximum ramp pressure in excess of 2 %.

3. The transducer output shall indicate the actual pressure to within $\pm 1\%$ in 0.2 s or less after attainment of maximum ramp pressure, and shall remain within this error band for the duration of applied steady-state pressure.

S2.8.4.5 Warm-Up Time—The transducer output shall attain a value within $\pm 1\%$ of the steady-state output with no overshoot in excess of 1 %. Output shall reach this band within 1 min after the transducer is energized and shall remain in this band.

S2.8.4.6 Ripple—The transducer rms output ripple shall not be greater than 0.5 %.

S2.8.4.7 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The maximum difference between outputs at any voltage and frequency or voltage (for dc) condition and the normal (115-V, 60-Hz, or 28-V dc) at the same input and test temperature (differential shall be included for Type D) shall not exceed 1 %.

S2.8.4.8 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc):

S2.8.4.8.1 Voltage—During the voltage transient test, the transducer output shall remain within $\pm 0.5\%$ of the pre-transient output.

S2.8.4.8.2 Frequency—During the frequency transient test, the transducer output shall remain within $\pm 0.5\%$ of the pre-transient output.

S2.8.4.9 Power interruption—During the power interruption test, the transducer performance shall conform to S2.8.4.1.

S2.8.4.10 Common Mode Pressure (Type D Only)—During the common mode pressure test, transducer performance shall be within the range formed by extending the upper and lower static error band limits specified in S2.8.4.1 by a percentage equal to:

\[
\frac{1}{10} \times \text{(system pressure rating)} \times \frac{1}{3} \times \text{differential pressure range}
\]

S2.8.4.11 Temperature—During the temperature test, the transducer performance shall be within the static error band specified in S2.8.4.1.

S2.8.4.12 Enclosure—The sensor head and optoelectronics module shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S2.8.4.13 Overpressure—Calibration conducted after over-pressure test shall have no values in excess of 1 % deviation from the pre-over-pressure test reference measurement.

S2.8.4.14 Line Pressure (Type D Only)—After the line pressure test, transducer performance shall be within the static error band specified in S2.8.4.1.

S2.8.4.15 Pressure Cycling—Calibration conducted after completion of pressure cycling test shall have no values in excess of 1 % deviation from pre-test reference measurement.

S2.8.4.16 Vibration—Monitored transducer output during all phases of the vibration test shall show no variation from steady-state output in excess of 2 %. There shall be no visible evidence of damage to the transducer as a result of the vibration test.

S2.8.4.17 Shock—The transducer shall operate during and after the shock test. After the shock test, the transducer output shall have no value in excess of 1 % deviation from the pre-shock test reference measurement. There shall be no visual evidence of damage to the transducer as a result of the shock test.

S2.8.4.18 Burst Pressure—The transducer shall withstand the burst pressure specified in S2.11.2.19 without showing any evidence of leakage.

S2.8.4.19 Short-Circuit (Output Type A Only)—After the short-circuit test, the transducer shall exhibit no damage and shall conform to S2.8.4.1.

S2.8.4.20 Line Voltage Reversal (dc Power Supply Only)—The transducer shall conform to S2.8.4.1 after the line voltage reversal test.

S2.8.4.21 Insulation Resistance—The insulation resistance of the transducer shall be not less than 10 M$\Omega$. 

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**F 2070 – 00**
S2.8.4.22 Electromagnetic Interference (EMI) Emission and Susceptibility—The transducers shall meet the requirements of Table II of MIL-STD-461, except as modified as follows:

1. CE101—The test signal shall be applied only to the ac-power leads of the test sample.
2. CE102—The test signal shall be applied only to the ac-power leads of the test sample.
3. CS114—Only Limit Curve #2 shall apply with the frequency range limited from 10 kHz to 30 MHz.
4. RE101—Only the limit curve for 50 cm shall apply.
5. RS103—The frequency range shall be limited from 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

S2.9 Workmanship, Finish, and Appearance

S2.9.1 Transducer Cleaning—The manufacturer shall ensure that pressure transducers shall be free of all loose scale, rust, grit, filings, and other foreign substances and free of mercury, oil, grease, or other organic materials. In addition, the following shall apply:

1. Transducers for oxygen service, Application X (see S2.4.3), shall be clean gas calibrated, cleaned, and pressure connections capped.
2. Transducers for all other applications shall be freshwater or clean gas calibrated, cleaned, and pressure connections capped.

S2.9.2 Surface Finish—Surfaces of castings, forgings, molded parts, stampings, and machined and welded parts shall be free of defects such as cracks, pores, undercuts, voids, and gaps. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn through, warpage, or dimensional change as a result of heat from welding. There shall be no damage to adjacent parts resulting from welding.

S2.10 Number of Tests and Retests

S2.10.1 Test Specimen—see 10.1.

S2.11 Test Methods

S2.11.1 Test Conditions—Except where the following factors are the variables, the tests specified in S2.11.2 shall be conducted with the equipment under the following operating environmental conditions:

1. Ambient temperature shall be 23 ± 2°C.
2. Relative humidity shall be ambient.
3. Tests—Except for the warm-up time test (see S2.11.2.5), the transducer and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S2.11.2.1 Reference Measurement—A reference measurement consisting of a one-trial calibration with at least five equally spaced intervals over the entire transducer range both upscale and downscale shall be conducted when specified in the individual test. No adjustments to the transducer are permitted during the reference measurement.

S2.11.2.2 Static Error Band and Repeatability—The transducer shall first be flexed over its full-pressure range by slowly increasing and decreasing the applied pressure for six continuous cycles. The calibration measurement shall be made at a minimum of five equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error band of all calibration shall meet the requirements of S2.8.4.1. Repeatability shall meet the requirements of S2.8.4.2.

S2.11.2.3 Sensitivity Factor—The sensitivity factor shall be determined as follows: Provide an input pressure (differential pressure for Type D) to the transducer of 80 ± 5 % of span. Record the input pressure (differential pressure) and corresponding electrical output. Increase the pressure (differential pressure) by an amount not exceeding 1 % of span. Record both the new pressure (differential pressure) and corresponding new electrical output. Calculate the change in both applied pressure (differential pressure) and electrical output as a percentage of transducer span. Determine the ratio of electrical output percentage change to applied pressure (differential pressure) percentage change. Repeat this procedure for a pressure (differential pressure) decrease not exceeding 1 % of span. Performance shall conform to the requirements of S2.8.4.3.

S2.11.2.4 Response—A pressure (differential pressure for Type D) ramp consisting of a pressure (differential pressure for Type D) rise of at least 40 % of span occurring in not greater than 0.1 s shall be applied to the transducer. The maximum ramp pressure shall be maintained for at least 0.5 s and shall not vary by more than ±2 % of the transducer span. Performance shall conform to the requirements of S2.8.4.4.

S2.11.2.5 Warm-Up Time—The test shall be conducted to determine the elapsed time between the application of the line power to the transducer and the point at which the transducer output reaches the conditions specified in S2.8.4.5.

1. (1) Test Conditions—The transducer shall be subjected to the ambient temperature of the testing location, while de-energized, for not less than 2 h. Recording equipment and other auxiliary equipment shall be energized to ensure complete warm-up. An input pressure of 80 ± 5 % of span shall be applied to the transducer and maintained constant during this test. Performance shall conform to the requirements of S2.8.4.

S2.11.2.6 Ripple—Transducer output rms ripple shall be determined at an output pressure (differential pressure for Type D) of 80 ± 5 % of transducer span. Performance shall conform to the requirements of S2.8.4.6.

S2.11.2.7 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The transducer shall be operated at normal, maximum, and minimum steady-state voltages (dc) and at all possible combinations of normal, maximum, and minimum voltages and frequencies (ac). The ambient temperature shall also vary, with the transducer operated for at least 1 h at each test temperature before the first reference measurement (see S2.11.2.1). Reference measurements shall be performed at ambient temperatures of 0 ± 2°C, 25 ± 2°C, and 65 ± 2°C. Test temperatures shall be accomplished by varying temperature in steps of 10°C each (30 min for each step) until the desired ambient temperature is reached. Performance shall conform to the requirements of S2.8.4.7.

S2.11.2.8 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc)—Tests shall be conducted with a pressure (differential pressure for Type D) input signal equal to 80 ± 5 % of the transducer span. The transducer output shall be
monitored throughout the test. Performance shall conform to the requirements of S2.8.4.8.

S2.11.2.8.1 Transient Voltage:

1. Upper and Lower Limits of Steady-State Voltage—With the transducer operating at the upper and lower limits of steady-state ac voltage, the ac-powered transducer shall have a transient voltage of ±16 %, recovering to the steady-state band in 2 s, superimposed. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of ±2 V, respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S2.8.4.8.

S2.11.2.8.2 Transient Frequency (for ac-Powered Transducers):

1. Upper Limit of Steady-State Frequency—With the transducer operating at the upper limit of steady-state frequency, a transient frequency of +1.5 Hz recovering to the steady-state band in 2 s shall be superimposed. Performance shall conform to the requirements of S2.8.4.8.

2. Lower Limit of Steady-State Frequency—With the transducer operating at the lower limit of steady-state frequency, a transient frequency of −1.5 Hz recovering to the steady-state band in 2 s shall be superimposed. Performance shall conform to the requirements of S2.8.4.8.

S2.11.2.9 Power Interruption—An input pressure (differential pressure for Type D) of 80 ± 5 % of span shall be applied to the transducer and maintained constant during the test. With the transducer operating within the steady-state tolerances of voltage and frequency, the external power supply shall be interrupted for an interval of 3 to 4 s. The power supply shall then be reestablished to within steady-state tolerances. The transducer shall be operated at steady-state power for 1 min. The power supply shall then be interrupted for an interval of 30 s. This cycle shall be repeated three times. Performance shall conform to the requirements of S2.8.4.9.

S2.11.2.10 Common Mode Pressure (Transducer Type D Only)—The rated pressure of the transducer shall be applied simultaneously to both pressure ports. The pressure at the low-pressure port shall then be decreased in pressure increments specified in S2.11.2.1 to the specified transducer range and then increased in similar increments to the transducer-rated pressure. Performance shall conform to the requirements of S2.8.4.10.

S2.11.2.11 Temperature—The transducer shall operate normally (without alignment or adjustment) throughout the following temperature cycle. Tolerances in operating characteristics shall be as specified herein. Performance shall conform to the requirements of S2.8.4.11.

1. Hold the test temperature at 0 ± 2°C for at least 24 h. During the last hour of operation, a reference measurement shall be made (see S2.11.2.1).

2. Increase the test temperature in steps of 10° each, at 30 min for each step, until +65 ± 2°C is reached and hold at that temperature for at least 24 h. During the last hour of operation, a reference measurement shall be made (see S2.11.2.1).

3. Reduce the test temperature in steps of 10° each, at 30 min for each step, until +25 ± 2°C is reached and hold at that temperature for at least 24 h. During the last hour of operation, a reference measurement shall be made (see S2.11.2.1).

S2.11.2.12 Enclosure—The sensor head and optoelectronics module (Type 1 only) shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. Performance shall conform to the requirements of S2.8.4.12.

S2.11.2.13 Overpressure—Before the overpressure test, a reference measurement in accordance with S2.11.2.1 shall be made. The transducer shall be subjected to a pressure equal to 200 % of the upper limit of its range for a period of 30 min. Within 10 min after release of this pressure, a reference measurement (see S2.11.2.1) shall be made for comparison. Performance shall conform to the requirements of S2.8.4.13.

S2.11.2.14 Line Pressure (for Type D Only)—The transducer shall successfully withstand the pressure rating, when applied to the high-pressure port with the low-pressure port vented to atmosphere, for a period of 10 min. The preceding shall be repeated with the pressure applied to the low-pressure port of the transducer. After each test, a reference measurement in accordance with S2.11.2.1 shall be made. Performance shall conform to S2.8.4.14.

S2.11.2.15 Pressure Cycling—Before performing the pressure cycling test, a reference measurement shall be made (see S2.11.2.1). The test shall be conducted by applying a periodic pressure change of not more than 20 % of span to not less than 80 % of span for a total of 260 000 cycles. The rate of cycling shall be within the range from 0.25 to 2 Hz. The transducer shall be energized throughout the test. After completion of the pressure cycling test, a reference measurement shall be made for comparison (see S2.11.2.1). Performance shall conform to the requirements of S2.8.4.15.

S2.11.2.16 Vibration—A reference measurement (see S2.11.2.1) shall be made before the vibration test. The transducer shall be tested in accordance with Type I (environmental) vibration of MIL-STD-167-1 except that the upper frequency shall be 175 Hz; the amplitude of vibration shall be in accordance with Table S2.2; and for the variable frequency portion, the vibration level shall be maintained for two minutes at each integral value of frequency. If no resonances are observed, the 2-h endurance test shall be conducted at 175 Hz. During the vibration test, a fluid pressure of 80 ± 5 % of the transducer span shall be applied to the transducer. Transducer output during the test shall be monitored. Performance shall conform to the requirements of S2.8.4.16.

<table>
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<td>101 to 175</td>
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<tr>
<td>Inch-Pound Units, in.</td>
</tr>
<tr>
<td>5 to 20</td>
</tr>
<tr>
<td>21 to 50</td>
</tr>
<tr>
<td>51 to 100</td>
</tr>
<tr>
<td>101 to 175</td>
</tr>
</tbody>
</table>
S2.11.2.17 Shock—The shock tests shall be conducted in accordance with Grade A, Class 1, Type C using bulkhead mounting fixture 4-A of MIL-S-901. During the test, a fluid pressure of 80 ± 5 % of the transducer span shall be applied to the transducer. The transducer output during the test shall be monitored. Before and after the shock test, reference measurements shall be made for comparison. Performance shall conform to the requirements of S2.8.4.18.

S2.11.2.18 Burst Pressure—The transducer shall be subjected to a liquid pressure equal to 300 % of the upper limit of its range applied to the transducer for a period of 10 min. The transducer shall conform to the requirements of S2.8.4.18. No performance test shall be required after the burst pressure test. A reference measurement (see S2.11.2.1) shall be recorded for information purposes.

S2.11.2.19 Short-Circuit (Output Type A Only)—An input pressure (differential pressure for Type D) of 80 ± 5 % of span shall be applied to the transducer and maintained constant during the test. The transducer shall be de-energized. The electrical output pins of the optoelectronics module shall be connected together with no load resistance. The transducer shall be energized for 5 min. Immediately following the 5-min period, the output pins shall be unshorted. The transducer shall conform to the requirements of S2.8.4.19.

S2.11.2.20 Line Voltage Reversal (dc Power Supply Only)—An input pressure (differential pressure for Type D) of 80 ± 5 % of span shall be applied to the transducer and maintained constant during the test. The positive 28-Vdc signal shall be applied to Connector Pin B. The dc reference signal shall be applied to Connector Pin A. The transducer shall be energized for a period of 10 min and then disconnected. The power shall then be correctly applied (Pin A positive, Pin B negative). A reference measurement shall be made (see S2.11.2.1). The transducer shall conform to the requirements of S2.8.4.20.

S2.11.2.21 Insulation Resistance—The insulation resistance of the transducer shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The relative humidity shall be 50 ± 10 %. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance meets the specified limit (see S2.8.4.21) and is steady or increasing, the test may be terminated before the end of the 2-min period.

S2.11.2.22 EMI Emission and Susceptibility—The EMI tests shall be in accordance with the test methods specified in MIL-STD-461, with the modifications as specified in S2.8.4.22. Performance shall conform to the requirements of S2.8.4.22.

S2.12 Inspection

S2.12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

S2.12.1.1 First-article tests (see S2.12.2).
S2.12.1.2 Conformance tests (see S2.12.3).

S2.12.2 First-Article Tests—First-article tests shall be performed before production. First-article tests shall be performed on samples that have been produced with equipment and procedures normally used in production. First-article tests shall consist of the examination and tests specified in Table S2.3. Failure of any pressure transducer to meet the requirements of this specification shall cause for rejection.

S2.12.2.1 First-Article Tests Sample Size—Two transducers of each lot shall be subjected to first-article testing, Table S2.3. One sample shall be subjected to the tests of Group I and one sample shall be subjected to the tests of Group II of Table S2.3. The fiber-optic connecting cable shall not be less than 100 ft.

S2.12.2.2 Order of First-Article Tests—The sample transducers shall be subjected to the tests specified in Table S2.3 in the order listed except that the steady-state supply voltage and frequency inspection may be performed concurrently with the temperature inspection. Any deviation in the test order shall first be approved by the purchaser.

S2.12.3 Conformance Tests—Each lot of transducers offered for delivery shall be subjected to the tests of Table S2.4.

S2.12.3.1 Group A Tests—All transducers offered for delivery shall be subjected to Group A tests as listed in Table S2.4. Failure of any transducer to meet the requirements of this specification shall be cause for rejection.

S2.12.3.2 Group B Tests—Group B tests shall be as listed in Table S2.4. The number of samples subjected to Group B tests shall be in accordance with Table S2.5. Failure of any transducer to meet the requirements of this specification shall be cause for rejection.

S2.12.4 General Examination—Each transducer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. Examination shall include a check of

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TABLE S2.3 First-Article Tests

<table>
<thead>
<tr>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group I</th>
<th>S2.11.2.2</th>
<th>S2.8.4.1 and S2.8.4.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static error band and repeatability</td>
<td>S2.11.2.2</td>
<td>S2.8.4.1 and S2.8.4.2</td>
</tr>
<tr>
<td>Sensitivity factor</td>
<td>S2.11.2.3</td>
<td>S2.8.4.3</td>
</tr>
<tr>
<td>Response</td>
<td>S2.11.2.4</td>
<td>S2.8.4.4</td>
</tr>
<tr>
<td>Warm-up time</td>
<td>S2.11.2.5</td>
<td>S2.8.4.5</td>
</tr>
<tr>
<td>Ripple</td>
<td>S2.11.2.6</td>
<td>S2.8.4.6</td>
</tr>
<tr>
<td>Supply voltage and frequency (steady-state)</td>
<td>S2.11.2.7</td>
<td>S2.8.4.7</td>
</tr>
<tr>
<td>Supply voltage and frequency (transient)</td>
<td>S2.11.2.8</td>
<td>S2.8.4.8</td>
</tr>
<tr>
<td>Power interruption</td>
<td>S2.11.2.9</td>
<td>S2.8.4.9</td>
</tr>
<tr>
<td>Common mode pressure (transducer Type D only)</td>
<td>S2.11.2.10</td>
<td>S2.8.4.10</td>
</tr>
<tr>
<td>Temperature</td>
<td>S2.11.2.11</td>
<td>S2.8.4.11</td>
</tr>
<tr>
<td>Enclosure</td>
<td>S2.11.2.12</td>
<td>S2.8.4.12</td>
</tr>
<tr>
<td>Overpressure</td>
<td>S2.11.2.13</td>
<td>S2.8.4.13</td>
</tr>
<tr>
<td>Line pressure (transducer Type D only)</td>
<td>S2.11.2.14</td>
<td>S2.8.4.14</td>
</tr>
<tr>
<td>Pressure cycling</td>
<td>S2.11.2.15</td>
<td>S2.8.4.15</td>
</tr>
<tr>
<td>Vibration</td>
<td>S2.11.2.16</td>
<td>S2.8.4.16</td>
</tr>
<tr>
<td>Shock</td>
<td>S2.11.2.17</td>
<td>S2.8.4.17</td>
</tr>
<tr>
<td>Burst pressure</td>
<td>S2.11.2.18</td>
<td>S2.8.4.18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group II</th>
<th>S2.11.2.2</th>
<th>S2.8.4.1 and S2.8.4.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-circuit (output Type A only)</td>
<td>S2.11.2.19</td>
<td>S2.8.4.19</td>
</tr>
<tr>
<td>Line voltage reversal (dc power supply only)</td>
<td>S2.11.2.20</td>
<td>S2.8.4.20</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S2.11.2.21</td>
<td>S2.8.4.21</td>
</tr>
<tr>
<td>EMI emission and susceptibility</td>
<td>S2.11.2.22</td>
<td>S2.8.4.22</td>
</tr>
</tbody>
</table>
all adjustments, if applicable. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with applicable approved industry standards.

S2.13 Certification
S2.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer’s facility for review by the purchaser upon request.

S2.14 Product Marking
S2.14.1 Label Plates—A label plate with engraved or stamped markings shall be permanently affixed to the sensor head and to the optoelectronics module.

S2.14.1.1 Sensor Head—At a minimum, the following information shall be provided on the label plate:
1. “SENSOR HEAD,”
2. Manufacturer’s name,
3. Manufacturer’s serial number,
4. Manufacturer’s part number and drawing number,
5. Designation,
6. National Stock Number (NSN), if available, and
7. Date of manufacture.

S2.14.1.2 Optoelectronics Module—At a minimum, the following information shall be provided on the label plate:
1. “OPTOELECTRONICS MODULE,”
2. Manufacturer’s name,
3. Manufacturer’s serial number,
4. Manufacturer’s part number,
5. Electrical and optical (if any) output (see S2.8.3),
6. National Stock Number (NSN), if available, and
7. Date of manufacture.

S2.14.2 Labeling—Labels shall be permanently and prominently marked.

S2.14.2.1 The legend “USE NO OIL FOR CALIBRATION” shall be marked on the sensor head housing.

S2.14.2.2 The legend “DO NOT LUBRICATE” shall be marked on the sensor head housing.

S2.14.2.3 A visible label, consisting of yellow lettering on a black background, shall be affixed to the outside of the optoelectronics module cover and shall contain the following:

NOTICE
UNTERMINATED OPTICAL CONNECTIONS MAY EMIT LASER RADIATION
DO NOT VIEW BEAM WITH OPTICAL INSTRUMENTS AND AVOID DIRECT EXPOSURE TO THE BEAM

S2.15 Packaging and Package Marking
S2.15.1 Packaging and package marking shall be in accordance with Section 15.

S2.16 Quality Assurance
S2.16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to effectively control the quality of the product being supplied, unless otherwise specified in the acquisition requirements (see S2.5.2).

S2.16.2 Warranty—Any special warranty requirements shall be specified in the acquisition requirements (see S2.5.2).

The following supplementary requirement, established for naval shipboard application, shall apply when specified in the contract or purchase order. When there is conflict between this specification and this supplementary requirement, this supplementary requirement shall take precedence.

S3. TRANSUCERS, SMART PRESSURE AND DIFFERENTIAL PRESSURE (ELECTRICAL)

S3.1 Scope
S3.1.1 This supplementary requirement covers the requirements for smart pressure and differential pressure transducers designed to meet the requirements for use onboard naval ships.

S3.1.2 The values stated in S1 units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in S1 units.

S3.2 Referenced Documents
S3.2.1 ISO Standard:
6149-1 Connections for Fluid Power and General Use—Ports and Stud Ends with ISO 261 Threads and O-Ring Sealing—Part 1: Ports with O-Ring Seal in Truncated Housing

S3.2.2 NEMA Standard:
250 Enclosures for Electrical Equipment (1000 Volts Maximum)\textsuperscript{5}  

S3.2.3 **Military Standards:**  
MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for\textsuperscript{6}  
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)\textsuperscript{6}  
MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of\textsuperscript{6}  

**S3.3 Terminology**  
S3.3.1 Terminology is consistent with that of Section 3 and the referenced documents.  

**S3.4 Classification**  
S3.4.1 **Designation**—For this specification, pressure transducer designations shall be assigned in accordance with S3.5.1 and listed in the following format:  

\textbf{Example:} F25XMS3-D-F-DC-2-10KD  

S3.4.2 **Types**—The following designators have been established for the various types of transducers:  
D—Pressure, differential  
P—Pressure (gage, absolute and sealed)  
V—Pressure, vacuum  
C—Pressure, compound  

S3.4.3 **Application**—The following application designations have been established for the corresponding process media:  
F—Freshwater, oil, condensate, steam, nitrogen and other inert gases  
S—Seawater  
G—Flue gas and ammonia  

S3.4.4 **Power Supply**—Transducers shall operate with dc input power. The designator shall be as follows:  
DC—Direct current supply  

S3.4.5 **Output**—The default dc electrical signal output of the transducer shall be designated by the following designators:  
2—4 mA  
3—1 to 5 V  
4—0.8 to 3.2 V  

S3.4.6 **Range**—The pressure range of the transducer shall be designated by two parts. The first part shall be the designator for the upper range value. The second part shall be the designator for the upper range unit of measure (see S3.4.6.1). The transducer pressure ranges shall be in accordance with Table S3.1.  

S3.4.6.1 **Units**—The units shall be designated by the corresponding letter designator and are limited to the following:  

\begin{tabular}{|c|c|c|c|}
\hline  
Letter & SI Units & Inch-Pound Units & \\
\hline  
V & KPaV—kiloPascals, vacuum & Hg—incches of mercury vacuum & \\
A & KPaA—kiloPascals, absolute & psia—pounds per square inch, absolute & \\
D & KPaD—kiloPascals, differential & psid—pounds per square inch, differential & \\
G & kPaG—kiloPascals, gauge & psg—pounds per square inch,gage & \\
S & kPaS—kiloPascals, sealed at 101.4 kPaA & psis—pounds per square inch, sealed at 14.7 psia & \\
W & kPaW—kiloPascals, water column, WC—and inches of water column & & \\
N & kPaWD—kiloPascals, water column, Differential & & \\
\hline  
\end{tabular}  

S3.5 **Ordering Information**  
S3.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data in accordance with S3.5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.  

S3.5.2 **Acquisition Requirements**—Acquisition documents shall specify the following:  
S3.5.2.1 Title, number, and date of this specification.  
S3.5.2.2 Part designation required (see S3.4.1).  
S3.5.2.3 National Stock Number (NSN), if available.  
S3.5.2.4 Mounting method, if other than specified herein (see S3.7.2).  
S3.5.2.5 Type of pressure connection, if other than specified herein (see S3.7.5).  
S3.5.2.6 Type of electrical connection, if other than specified herein (see S3.7.4).  
S3.5.2.7 Quantity of transducers required.  
S3.5.2.8 Quantity of handheld communicators required (see S3.7.8).  
S3.5.2.9 If deviation requests are not required when departing from material guidance (see S3.6).  
S3.5.2.10 When the first article inspection is required (see S3.12.3).  
S3.5.2.11 Special product marking requirements (see S3.13).  
S3.5.2.12 Special packaging or package marking requirements (see S3.14).  

\begin{table}[h]  
\centering  
\caption{Range}  
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline  
 & Type D & Type P & Type C & Type V & \\
 & SI Units & & & & & & & & \\
\hline  
\multicolumn{8}{|c|}{S} & \\
Differential Pressure Ranges, kPaD & Differential Pressure Water Column Ranges, kPaWD & Pressure Ranges, kPaA, or kPaS\textsuperscript{4} & Water Column Ranges, kPaW & Compound Ranges, kPaV & Vacuum Range, kPaV & \\
Range Designator & Range Designator & Range Designator & Range Designator & Range Designator & Range Designator & \\
0-10 000 & 10K & 0-7000 & 7K & 0-10 000 & 10K & 0-100 & \\
\hline  
\multicolumn{8}{|c|}{\text{Inch-Pound Units}} & \\
Differential Pressure Ranges, psid & Differential Pressure Water Column Ranges, WC & Pressure Ranges, psig, psia, or psis\textsuperscript{4} & Water Column Ranges, WC & Compound Ranges, Hg-0-psig & Vacuum Range, Hg & \\
Range Designator & Range Designator & Range Designator & Range Designator & Range Designator & Range Designator & \\
0-1 500 & 10K & 0-1 000 & 7K & 0-1 500 & 10K & 0-1 000 & 30-0-600 & 4K & 0-30 & 100 & \\
\hline  
\end{tabular}  
\footnotesize{\textsuperscript{4}For upper range values of 7000 kPa (1000 lb/in.\textsuperscript{2}) and above.}  
\end{table}
S3.5.2.13 When ISO 9001 quality assurance system is not required (see S3.16.1).
S3.5.2.14 Special warranty requirements (see S3.16.2).
S3.5.3 First-Article Tests—When first-article testing is required, the purchaser should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first-article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer’s current inventory. The number of items to be tested in accordance with S3.12.3 should be specified. The purchaser should also include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article testing to those manufacturers offering a product which has been previously acquired or tested by the purchaser; and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S3.6 Materials
S3.6.1 Metals—Unless otherwise specified herein, all metals used in the construction of the transducer shall be corrosion-resistant or treated to provide corrosion resistance. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion. The materials for the sensing element and wetted parts shall be selected for long-term compatibility (see S3.8.1) with the process medium (see S3.4.3).
S3.6.2 Flammable Materials—Materials used in the construction of the transducer shall in the end configuration be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application. Fire retardance shall not be achieved by use of nonpermanent additives to the material.
S3.6.3 Fungus-Resistant Materials—Materials used in the construction of the sensor shall not support the growth of fungus.
S3.6.4 Solvents, Adhesives, and Cleaning Agents—When chemicals or cements are used in bonding of internal transducer components, no degradation shall result during in-service use.

S3.7 Physical Properties
S3.7.1 Enclosure—The transducer body and pressure cavity shall be environmentally sealed unless specified. The transducer enclosure shall be Type 4X in accordance with NEMA Standard 250.
S3.7.2 Transducer Mounting—The transducer shall be mounted on an integral coplanar flange/bracket, as shown in Fig. S3.1, for interface with the process medium. For Types P, V, and C transducers, the equalizing valve control handles shall be removed and equalizing valve ports shall be blanked.
S3.7.3 External Configuration—The transducer shall have an external configuration within the boundaries established by Figs. S3.1 and S3.2.

S3.7.4 Electrical Connection—A terminal block shall be provided in the transducer for connection of electrical conductors for power supply input, dc electrical signal output, and transducer case ground.
S3.7.5 Pressure Connections—The pressure connections that interface with shipboard systems shall be M12 × 1.5 (¾–20 UNF-2B) tube connection in accordance with ISO 6149-1. The traditional flange (see Fig. S3.2) provides these connections for differential pressure units and the flat adapter (see Fig. S3.3) provides these connections for pressure units. Differential units shall mount on the traditional flange and pressure units shall interface with the flat adapter.
S3.7.6 Digital Meter—The transducer shall have a direct reading digital meter to display pressure in pressure engineering units and in percent of analog range values. The meter shall display diagnostic messages for local troubleshooting. The meter shall be capable of being rotated 90° clockwise or counterclockwise within the transducer housing for meter reading flexibility.
S3.7.7 Communications Protocol—The transducer shall be microprocessor-based. The transducer shall be capable of digital communications with field devices using the frequency shift keying Highway Addressable Remote Transducer (HART) protocol supported by the HART Communication Foundation. Using the HART protocol, the transducer shall be capable of providing analog signal output (see 3.8.3) and digital communications over the same pair of wires.
S3.7.8 Handheld Communicator—A handheld communicator shall be provided when specified (see S3.5.2). The handheld communicator shall enable communication by an operator with the transducer using the HART protocol. The handheld communicator shall enable communicating with the transducer for configuration, test, and detailed setup of the transducer (see 3.8.5.2).
S3.7.9 Lubrication—The transducer shall operate without lubrication of moving parts after assembly.
S3.7.10 Damping—The use of a media for damping in transducers shall be cited on the equipment drawing.
S3.7.12 Weight—The weight of a transducer shall not exceed 2.7 kg (6 lb). The weight of a traditional flange/bracket shall not exceed 2.7 kg.

S3.8 Performance Requirements
S3.8.1 Service Life—The transducer shall be constructed for a life of 25 years of operation and shall meet the requirements specified herein when operated in the naval shipboard environment.
S3.8.2 Input Power—The transducer shall be designed to operate using 28 ± 4.5 Vdc power. The transducer shall operate with power supply variations as specified in S3.11.2.10 and S3.11.2.13.
S3.8.3 Output—The electrical signal output of the transducer shall be dc, directly proportional to the pressure or differential pressure input. The output shall be a true current source or true voltage source. The output type shall be selectable via a handheld communicator (see S3.7.8) or other device using the HART protocol. Selectable output types shall be 4 to 20 mA, 1 to 5 V, and 0.8 to 3.2 V.
S3.8.3.1 Current Output—When a 4- to 20-mA current output is selected, the requirements specified herein shall be met regardless of external load resistance variations over a range from 0 to 250 Ω. The 4-mA output shall correspond to the lower pressure or differential pressure range value and the 20-mA output shall correspond to the upper pressure or differential pressure range value for the transducer span programmed into the transducer (see S3.8.3.3).

S3.8.3.2 Voltage Output—When a voltage output is selected, the requirements specified herein shall be met for external load resistance exceeding 100 000 Ω. The 1- or 0.8-V output (output Type 3 or 4, respectively) shall correspond to the lower pressure or differential pressure range value for the transducer span programmed into the transducer (see 3.8.3.3). The 5- or 3.2-V output (output Type 3 or 4, respectively) shall correspond to the upper pressure or differential pressure range value for the transducer span programmed into the transducer (see 3.8.3.3).

S3.8.3.3 Floating (Live) Zero—The transducer shall be capable of assigning the low output value (4 mA, 1 V, or 0.8 V) to any pressure value within the programmed transducer span. The transducer shall be capable of assigning the high output value (20 mA, 5 V, or 3.2 V) to any pressure value within the programmed transducer span that is higher than the low output pressure value.

S3.8.4 Pressure Ports (Transducer Type D Only)—The transducer shall be capable of operation with either pressure port as the high-pressure port and the other as the low-pressure port. Selection of high- and low-pressure ports shall be programmable from a remote device using the HART protocol.

S3.8.5 Transducer Performance—Unless otherwise specified, performance tolerances are specified in percent of transducer output span for each settable span.

S3.8.5.1 Rangeability—Rangeability of the transducer shall be 100 to 1. Span values shall be settable anywhere within the range limits. Minimum span shall be no more than 1 % of the upper range value.

S3.8.5.2 Communications—The transducer shall be capable of communication with field devices using the HART protocol (see S3.7.8). The transducer shall be programmed such that

<table>
<thead>
<tr>
<th>Dimension</th>
<th>mm</th>
<th>in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>85.0 max</td>
<td>3.3 max</td>
</tr>
<tr>
<td>B</td>
<td>165.0 max</td>
<td>6.4 max</td>
</tr>
<tr>
<td>C</td>
<td>205.0 max</td>
<td>8.0 max</td>
</tr>
</tbody>
</table>

NOTE 1—Dimension tolerance is ±1.25 mm (0.05 in.), unless otherwise specified.

NOTE 2—The pressure port(s) shall be generally located as shown. Differential pressure transducer ports shall be located to match traditional flange/bracket configuration.

FIG. S3.1 Transducer External Configuration Boundary Limits
field device operators can perform configuration, test, and detailed setup of the transducer.

S3.8.5.2.1 Configuration—In the configuration mode, field device operators shall be capable of the adjustment of transducer operational parameters including, but not limited to, linear or square root output, damping, engineering unit selection, and assigning high and low pressure ports (differential transducers). The field device operator shall be capable of entering informational data for identification and physical description of the transducer. Informational data shall include tag, descriptor, and message fields for the transducer, date, flange type, flange material, drain/vent material, O-ring material, and remote seal information.

S3.8.5.2.2 Test—In the test mode, field device operators shall be capable of interrogation of the transducer when a problem has been detected. The field device operator shall be capable of being directed to give specific outputs for loop testing.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>mm</th>
<th>in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>41.3</td>
<td>1.625</td>
</tr>
<tr>
<td>B</td>
<td>54.0</td>
<td>2.125</td>
</tr>
<tr>
<td>C</td>
<td>15.9</td>
<td>0.625</td>
</tr>
<tr>
<td>D</td>
<td>9.6</td>
<td>0.375</td>
</tr>
<tr>
<td>E</td>
<td>12.7 dia</td>
<td>0.5 dia</td>
</tr>
<tr>
<td>F</td>
<td>11.2</td>
<td>0.4375 dia</td>
</tr>
<tr>
<td>G</td>
<td>60.5</td>
<td>2.375</td>
</tr>
<tr>
<td>H</td>
<td>12.7 dia</td>
<td>0.4375 dia</td>
</tr>
<tr>
<td>I</td>
<td>60.5</td>
<td>2.375</td>
</tr>
<tr>
<td>J</td>
<td>20.7</td>
<td>0.8125</td>
</tr>
<tr>
<td>K</td>
<td>13.5</td>
<td>0.531</td>
</tr>
<tr>
<td>L</td>
<td>93.7</td>
<td>3.6875</td>
</tr>
<tr>
<td>M</td>
<td>12.7</td>
<td>0.4375</td>
</tr>
<tr>
<td>N</td>
<td>31.75</td>
<td>1.25</td>
</tr>
<tr>
<td>P</td>
<td>188.9</td>
<td>7.4375</td>
</tr>
<tr>
<td>Q</td>
<td>6.35</td>
<td>0.25</td>
</tr>
<tr>
<td>R</td>
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<td>3.375</td>
</tr>
<tr>
<td>S</td>
<td>60.5</td>
<td>2.375</td>
</tr>
<tr>
<td>T</td>
<td>128.6</td>
<td>5.0625</td>
</tr>
<tr>
<td>U</td>
<td>101.6</td>
<td>4.0</td>
</tr>
<tr>
<td>V</td>
<td>6.35</td>
<td>0.25</td>
</tr>
<tr>
<td>W</td>
<td>M12×1.5</td>
<td>7/16-20UNF-2B</td>
</tr>
</tbody>
</table>

**FIG. S3.2 Traditional Flange/Bracket Configuration**

**NOTE 1—Dimension tolerance is ±1.25 mm (0.05 in.), unless otherwise specified.**
S3.8.5.2.3 Detailed Setup—The detailed setup mode is used during initial setup of the transducer and for maintenance of the digital electronics. Detailed setup shall include the setting of transducer zero and span values anywhere within available range limits, analog output selection, and transducer calibration. The field device operator shall be capable of selecting security features to prevent accidental or deliberate adjustment of analog output setpoints.

S3.8.5.3 Static Error Band—The transducer static error band shall not exceed \( \pm 0.25 \% \).

S3.8.5.4 Output—The output shall conform to S3.8.3 and the transducer performance shall be within the static error band specified in S3.8.5.3.

S3.8.5.5 Warm-Up Time—The transducer output shall attain a value within \( \pm 0.5 \% \) of the steady-state output with no overshoot in excess of 0.5%. Output shall reach this band within 2 s after the transducer is energized and shall remain in this band.

S3.8.5.6 Enclosure—The transducer shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S3.8.5.7 Repeatability—Repeatability of transducer output shall be within 0.5%.

S3.8.5.8 Sensitivity Factor—The sensitivity factor shall not be less than 0.75 nor more than 1.25.

S3.8.5.9 Stability and Temperature—The transducer shall remain within the static error band specified in S3.8.5.3 throughout the stability and temperature test.

S3.8.5.10 Ripple—Transducer rms output ripple shall not exceed 0.15% of full-scale dc output.

S3.8.5.11 Steady-State Supply Voltage—Maximum difference between outputs at any voltage condition and the normal (28-Vdc) at the same input and test temperature (differential pressure shall be included for Type D) shall not exceed 0.5%.

S3.8.5.12 Pressure Rating and Common Mode Pressure (Transducer Type D Only)—Type D transducers shall have a pressure rating of 21 MPa (3000 lb/in.\(^2\)). During the common mode pressure test, transducer performance shall be within the range formed by extending the upper and lower static error band limits specified in S3.8.5.3 by a percentage equal to:

\[
\frac{1}{10} \left( \frac{\text{System pressure rating}}{\text{Differential pressure range}} \right)^{1/3}
\]

S3.8.5.13 Response—Transducer output shall conform to the following criteria, where all percentages are of transducer span:

1. The transducer output shall be within \( \pm 2 \% \) of the maximum ramp pressure within 0.01 s of the time that pressure is attained.
2. The transducer output shall exhibit no overshoot of maximum ramp pressure in excess of 2%.
3. The transducer output shall indicate the actual pressure to within \( \pm 1 \% \) in 0.175 s or less after attainment of maximum ramp pressure, and shall remain within this error band for the duration of applied steady-state pressure.
S3.8.5.14 Transient Supply Voltage—During the voltage transient test, the transducer output shall remain within ±0.5 % of the pretransient output.

S3.8.5.15 Power Interruption—During the power interruption test, transducer performance shall conform to S3.8.5.3.

S3.8.5.16 Overpressure—Calibration conducted after overpressure test shall have no values in excess of 1 % deviation from the pre-overpressure test reference measurement.

S3.8.5.17 Line Pressure (Transducer Type D Only)—After the line pressure test, transducer performance shall be within the static error band specified in S3.8.5.3.

S3.8.5.18 Pressure Cycling—Calibration conducted after completion of pressure cycling test shall have no values in excess of 1 % deviation from pretest reference measurement.

S3.8.5.19 Insulation Resistance—The insulation resistance of the transducer shall be not less than 10 MΩ.

S3.8.5.20 Vibration—Monitored transducer output during all phases of vibration test shall show no variation from steady-state output in excess of 2 %. There shall be no visible evidence of damage to the transducer as a result of the vibration test.

S3.8.5.21 Shock—The transducer shall operate during and after the shock test. After the shock test, the transducer output shall have no value in excess of 1 % deviation from the pre-shock test reference measurement. There shall be no visual evidence of damage to the transducer as a result of the shock test.

S3.8.5.22 Burst Pressure—The transducer shall withstand the burst pressure specified in S3.11.2.21 without showing any evidence of leakage.

S3.8.5.23 Short-Circuit Test—After the short-circuit test, the transducer shall exhibit no damage and shall conform to S3.8.5.3.

S3.8.5.24 Line Voltage Reversal Test—The transducer shall conform to S3.8.5.3 after the line voltage reversal test.

S3.8.5.25 Electromagnetic Interference (EMI)—The transducers shall meet the requirements of Table II of MIL-STD-461, except as modified as follows:

(1) CE101—The test signal shall be applied only to the ac power leads of the test sample.

(2) CE102—The test signal shall be applied only to the ac power leads of the test sample.

(3) CS114—Only Limit Curve #2 shall apply with the frequency range limited from 10 kHz to 30 MHz.

(4) RE101—Only the limit curve for 50 cm shall apply.

(5) RS103—The frequency range shall be limited from 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

S3.9 Workmanship, Finish, and Appearance

S3.9.1 Transducer Cleaning—The manufacturer shall ensure that pressure transducers shall be free of all loose scale, rust, grit, filings and other foreign substances and free of mercury, oil, grease, or other organic materials. Transducers for all applications shall be freshwater or clean gas calibrated, cleaned, and pressure connections capped.

S3.10 Number of Tests and Retests

S3.10.1 Test Specimen—(see 10.1).

S3.11 Test Methods

S3.11.1 Test Conditions—Except where the following factors are the variables, the tests specified in S3.11.2 shall be conducted with the equipment under the following operating environmental conditions:

S3.11.1.1 Ambient temperature shall be 23 ± 2°C.

S3.11.1.2 Relative humidity shall be ambient.

S3.11.1.3 Range Setting—The transducer has a rangeability from 100 to 1 (S3.8.5.1). All tests, excluding static error band and repeatability (S3.11.2.6), shall be conducted with the transducer set at approximately the mid range. Static error band and repeatability shall be accomplished at 3 ranges (low, medium, and high) within the capability of the transducer under test.

S3.11.2 Tests—Except for the warm-up time test (see S3.11.2.4), the transducer and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S3.11.2.1 Reference Measurement—A reference measurement consisting of a one-trial calibration with at least five equally spaced intervals over the entire transducer range both upscale and downscale shall be conducted when specified in the individual test.

S3.11.2.2 Communications—The test shall be conducted with a handheld communicator using the HART protocol. Configuration, test, and detailed setup of the transducer shall be performed. In the test mode, transducer problems shall be simulated to verify test mode functions. Performance shall conform to S3.8.3, S3.8.4, S3.8.5.1, and S3.8.5.2. All handheld communicator functions shall be verified.

S3.11.2.3 Output—Three reference measurements shall be made in accordance with S3.11.2.1. Each reference measurement shall use a different set of low- and high-output values (see S3.8.3.3). Performance shall conform to the requirements of S3.8.5.4.

S3.11.2.4 Warm-Up Time—The test shall be conducted to determine the elapsed time between the application of line power to the transducer and the point at which the transducer output reaches the conditions specified in S3.8.5.5.

S3.11.2.4.1 Test Conditions—The transducer shall be subjected to the ambient temperature of the testing location, while deenergized, for not less than 2 h. Recording equipment and other auxiliary equipment shall be energized to ensure complete warm-up. An input pressure (differential pressure for Type D) of 80 ± 5 % of the transducer upper range limit shall be applied to the transducer and maintained constant during this test. Performance shall conform to S3.8.5.

S3.11.2.5 Enclosure—The enclosure shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. Performance shall conform to S3.8.5.6.

S3.11.2.6 Static Error Band and Repeatability—The transducer shall first be flexed over its full pressure range by slowly increasing and decreasing the applied pressure for six continuous cycles. The calibration measurement shall be made at a minimum of five equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error...
band of all calibrations shall meet the requirements of S3.8.5.3. Repeatability shall meet the requirements of S3.8.5.7.

S3.11.2.7 Sensitivity Factor—The sensitivity factor shall be determined as follows: Provide a pressure (differential pressure for transducer Type D) to the transducer of 80 ± 5 % of transducer upper range limit. Record the input pressure (differential pressure) and corresponding electrical output. Increase the pressure (differential pressure) by an amount not exceeding 1 % of upper range limit. Record both the new pressure (differential pressure) and corresponding new electrical output. Calculate the change in both applied pressure (differential pressure) and electrical output as a percentage of transducer range. Determine the ratio of electrical output percentage change to applied pressure (differential pressure) percent change. Repeat this procedure for a pressure (differential pressure) decrease not exceeding 1 % of upper range limit. Performance shall conform to the requirements of S3.8.5.8.

S3.11.2.8 Stability and Temperature—The transducer shall be operated at an input pressure (differential pressure for transducer Type D) of 80 ± 5 % of transducer upper range limit for a period of ten days. Starting ambient temperature shall be 25 ± 2°C. At the end of three days, the ambient temperature shall be changed to 0 ± 2°C. At the end of five days, the ambient temperature shall be changed to 65 ± 2°C. At the end of seven days, the ambient temperature shall be returned to 25 ± 2°C. Performance shall conform to the requirements of S3.8.5.9.

S3.11.2.9 Ripple—Transducer output rms ripple shall be determined at an input pressure (differential pressure for transducer Type D) of 80 ± 5 % of transducer upper range limit. Performance shall conform to the requirements of S3.8.5.10.

S3.11.2.10 Steady-State Supply Voltage—The transducer shall be operated at normal, maximum, and minimum steady-state voltages (dc). Performance shall conform to S3.8.5.11.

S3.11.2.11 Common Mode Pressure (Transducer Type D Only)—The rated pressure of the transducer shall be applied simultaneously to both pressure ports. The pressure at the assigned low-pressure port shall then be decreased in pressure increments specified in S3.11.2.1 to the specified transducer range and then increased in similar increments to the transducer-rated pressure. Performance shall conform to S3.8.4 and S3.8.5.12. The test shall be conducted once with each pressure port as the assigned low-pressure port.

S3.11.2.12 Response—A pressure (differential pressure for Type D) ramp consisting of a pressure (differential pressure for Type D) rise of at least 40 % of transducer upper range limit occurring at the rate of not less than 400 % per second shall be applied to the transducer. The maximum ramp pressure shall be maintained for at least 0.50 s and shall not vary by more than ±2 % of the transducer upper range limit. Performance shall conform to S3.8.5.13.

S3.11.2.13 Transient Supply Voltage—Tests shall be conducted with a pressure (differential pressure for transducer Type D) input signal equal to 80 ± 5 % of the transducer upper range limit. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of no more than ±2 V, respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S3.8.5.14.

S3.11.2.14 Power Interruption—An input pressure (differential pressure for transducer Type D) of 80 ± 5 % of transducer upper range limit shall be applied to the transducer and maintained constant during the test. With the transducer operating within the steady-state voltage tolerances, the external power supply shall be interrupted for an interval of 3 to 4 s. The power supply shall then be reestablished to within steady-state tolerances. The transducer shall be operated at steady-state power for 1 min. The power supply shall then be interrupted for an interval of 30 s. This cycle shall be repeated three times. Performance shall conform to the requirements of S3.8.5.15.

S3.11.2.15 Overpressure—Before the overpressure test, a reference measurement in accordance with S3.11.2.1 shall be made. The transducer shall successfully withstand pressure (differential pressure for transducer Type D) equal to 200 % of its upper range limit with a maximum pressure of 85 MPa (12 000 lb/in.²) for a period of ½ h. At the end of this period, transducers shall be immediately subjected to a pressure equal to 7 kPa (1 lb/in.²) or 10 % of upper range limit, whichever is less, below atmospheric for an additional period of ½ h. Within 10 min after release of this pressure, a reference measurement (see S3.11.2.1) shall be made for comparison. Performance shall conform to S3.8.5.16. For Type D only, if the line pressure rating exceeds 200 % of the maximum differential pressure range, the overpressure test shall be omitted and 0.5 % deviation shall be applied to the line pressure test (see S3.11.2.16).

S3.11.2.16 Line Pressure (for Transducer Type D Only)—The transducer shall successfully withstand the pressure rating, when applied to one pressure port with the other pressure port vented to the atmosphere for a period of 10 min. The preceding shall be repeated with the pressure applied to the opposite pressure port of the transducer. After each test, a reference measurement in accordance with S3.11.2.1 shall be made. Performance shall conform to S3.8.5.17.

S3.11.2.17 Pressure Cycling—Before performing the pressure cycling test, a reference measurement shall be made (see S3.11.2.1). The test shall be conducted on a suitable system by applying a periodic pressure change of not more than 20 % to not less than 80 % of upper range limit for a total of 260 000 cycles. The rate of cycling shall be within the range from 0.25 to 2 Hz. The transducer shall be energized throughout the test. After completion of the pressure cycling test, a reference measurement shall be made for comparison (see S3.11.2.1). Performance shall conform to S3.8.5.18.

S3.11.2.18 Insulation Resistance—The insulation resistance of the transducer shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The relative humidity shall be 50 ± 10 %. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance
meets the specified limit (see S3.8.5.19) and is steady or increasing, the test may be terminated before the end of the two minute period.

S3.11.2.19 Vibration—The transducer shall be tested in accordance with Type I (environmental) vibration of MIL-STD-167-1. The following exceptions apply: the upper frequency shall be 175 Hz, the amplitude of vibration shall be in accordance with Table S3.2 for the variable frequency portion, and the vibration level shall be maintained for 2 min at each integral value of frequency. If no resonance frequencies are observed, the 2-h endurance test shall be conducted at 175 Hz. During the vibration test, a fluid pressure of 80 ± 5 % of the transducer upper range limit shall be applied to the transducer. Transducer output during the test shall be monitored. Performance shall conform to S3.8.5.20.

S3.11.2.20 Shock—The shock tests shall be conducted in accordance with Grade A, Class 1, Type C using bulkhead mounting fixture 4-A of MIL-S-901. During the test, a fluid pressure (differential pressure for transducer Type D) of 80 ± 5 % of the transducer upper range limit shall be applied to the transducer. The transducer output during the test shall be unshorted. The transducer shall be energized for 5 min. Immediately following shall be connected together with no load resistance. The electrical output terminals of the transducer shall first be approved by the purchaser. In Table S3.3 in the order listed. Any deviation in the test order shall be as specified in S3.8.5.23. Failure of any pressure transducer to meet the requirements of this specifica-
tion shall conform to S3.8.5.21.

S3.11.2.21 Burst Pressure—The transducer shall be subjected to a liquid pressure equal to 300 % of the upper range limit with a maximum pressure of 105 MPa (15 000 lb/in.²) applied to the transducer (simultaneously to both sides for transducer Type D) for a period of 10 min. The transducer shall conform to the requirements of S3.8.5.22. No performance test shall be required after the burst pressure test. A reference measurement (see S3.11.2.1) shall be recorded for information purposes.

S3.11.2.22 Short Circuit—An input pressure (differential pressure for transducer Type D) of 80 ± 5 % of transducer upper range limit shall be applied to the transducer and maintained constant during the test. The transducer shall be de-energized. The electrical output terminals of the transducer shall be connected together with no load resistance. The transducer shall be energized for 5 min. Immediately following the 5-min period, the output terminals shall be unshorted. The transducer shall conform to the requirements of S3.8.5.23.

S3.11.2.23 Line Voltage Reversal—An input pressure (differential pressure for transducer Type D) of 80 ± 5 % of transducer upper range limit shall be applied to the transducer and maintained constant during the test. The +28-Vdc conductor from the power supply shall be connected to the negative terminal on the transducer terminal board. The –28-Vdc conductor from the power supply shall be connected to the positive terminal on the transducer terminal board. The transducer shall be energized for a period of 10 min and then disconnected. The power shall then be correctly connected (positive conductor to positive terminal and negative conductor to negative terminal). A reference measurement shall be made (see S3.12.2.1). The transducer shall conform to the requirements of S3.8.5.24.

S3.11.2.24 EMI Tests—The EMI tests shall be in accordance with the test methods specified in MIL-STD-461, with the modifications as specified in S3.8.5.25. Performance shall be as specified in S3.8.5.25.

S3.12 Inspection

S3.12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

S3.12.1.1 First-article tests (see S3.12.3).
S3.12.1.2 Conformance tests (see S3.12.4).
S3.12.2 First-Article Tests—First-article tests shall be performed before production. First-article tests shall be performed on samples that have been produced with equipment and procedures normally used in production. First-article tests shall consist of the tests specified in Table S3.3. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S3.12.2.1 Order of First-Article Tests—With the exception of the electromagnetic interference emission and susceptibility test which may be conducted on separate transducers, the test specimens (transducers) shall be subjected to the tests specified in Table S3.3 in the order listed. Any deviation in the test order shall first be approved by the purchaser.

S3.12.3 Conformance Tests—Each pressure transducer in each lot offered for delivery shall be subjected to the tests listed

**TABLE S3.2 Amplitudes of Vibration**

<table>
<thead>
<tr>
<th>Frequency Range, Hz</th>
<th>Exploratory SI Units, mm</th>
<th>Variable Frequency SI Units, mm</th>
<th>Exploratory Inch-Pound Units, in.</th>
<th>Variable Frequency Inch-Pound Units, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 20</td>
<td>0.255 ± 0.050</td>
<td>0.765 ± 0.150</td>
<td>0.010 ± 0.002</td>
<td>0.030 ± 0.006</td>
</tr>
<tr>
<td>21 to 50</td>
<td>0.105 ± 0.025</td>
<td>0.510 ± 0.100</td>
<td>0.004 ± 0.001</td>
<td>0.020 ± 0.004</td>
</tr>
<tr>
<td>51 to 100</td>
<td>0.0380 ± 0.0075</td>
<td>0.255 ± 0.050</td>
<td>0.0015 ± 0.0003</td>
<td>0.010 ± 0.002</td>
</tr>
<tr>
<td>101 to 175</td>
<td>0.0100 ± 0.0025</td>
<td>0.0380 ± 0.0075</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in Table S3.4 and shall be conducted in the order listed. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S3.12.4 General Examination—Each transducer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with applicable approved industry standards.

S3.13 Certification
S3.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer’s facility for review by the purchaser upon request.

S3.14 Product Marking
S3.14.1 Label Plates—A label plate with engraved or stamped markings shall be permanently affixed to the transducer. At a minimum, it shall contain the following:
S3.14.1.1 PRESSURE TRANSDUCER" or “DIFFERENTIAL PRESSURE TRANSDUCER;”
S3.14.1.2 Manufacturer’s name,
S3.14.1.3 National Stock Number (NSN), if available,
S3.14.1.4 Date of manufacture,
S3.14.1.5 Designation, and
S3.14.1.6 Pressure rating for Type D transducers.
S3.14.2 Transducers for use with Application F shall have “USE NO OIL FOR CALIBRATION” prominently marked on the body.
S3.14.3 The legend “DO NOT LUBRICATE” shall be prominently marked on the body.

S3.15 Packaging and Package Marking
S3.15.1 Packaging and package marking shall be in accordance with Section 15.

S3.16 Quality Assurance
S3.16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see S3.5.2).
S3.16.2 Warranty—Any special warranty requirements shall be specified in the acquisition requirements (see S3.5.2).

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>General examination</td>
<td>S3.12.5</td>
<td>S3.6 and S3.7</td>
</tr>
<tr>
<td>Output</td>
<td>S3.11.2.3</td>
<td>S3.8.5.4</td>
</tr>
<tr>
<td>Static error band and repeatability</td>
<td>S3.11.2.6</td>
<td>S3.8.5.3 and S3.8.5.7</td>
</tr>
<tr>
<td>Sensitivity factor</td>
<td>S3.11.2.7</td>
<td>S3.8.5.8</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S3.11.2.18</td>
<td>S3.8.5.19</td>
</tr>
</tbody>
</table>

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Standard Specification for Switch, Position Proximity (Noncontact) or Limit (Mechanical Contact), Fiber-Optic

1. Scope

1.1 This specification covers the requirements for fiber-optic position switches (proximity and limit). This specification does not include switches that transfer an optical signal from one path to another by an external force or energy applied to the switch.

1.2 The values stated in SI units are to regarded as the standard. The values given in parentheses are for information only. Where information is to be specified, it shall be stated in SI units.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.4 Special requirements for naval shipboard applications are included in the Supplement.

2. Referenced Documents

2.1 ASTM Standards:
D 3951 Practice for Commercial Packaging

2.2 ISO Standards:
ISO 9001 Quality System—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing

3. Terminology

3.1 Definitions:
3.1.1 closed switch—the light path is complete; signal from transmitter to receiver is complete.

3.1.2 closed switch with positive alarm—the light path is complete. Signal level indicates that the end faces of the sensing element are dirty and require maintenance for continued proper operation.

3.1.3 fiber-optic position switch—a device that converts measured position, via changes in fiber-optic properties, to an output that is a function of the applied measurand. The fiber-optic position switch normally consists of a sensor head, optoelectronics module, and connectorized fiber-optic cable.

3.1.4 limit switch—a switch that senses a change in position via mechanical contact.

3.1.5 open switch—the light path is blocked; signal from transmitter to receiver is not complete.

3.1.6 optical transmittance change—the change in optical power level introduced by an environmental, mechanical, or other induced stress.

3.1.7 optoelectronics module—unit of the fiber-optic position switch that contains the optical transmitter and receiver, and signal conditioning electronics, necessary to convert the sensed position to the specified output signal. The optoelectronics module may be an expansion card for a microprocessor-based system, or a stand-alone unit.

3.1.8 proximity switch—a switch that senses a change in position via noncontact means.

3.1.9 sensor head—unit of the fiber-optic position switch that detects position via changes in optical properties. The optoelectronics module interrogates the sensor head to determine the position of the measurand. An optical signal is transmitted from the optoelectronics module to the sensor head. The optical path is either complete or blocked, depending on the status of the item being measured, giving an indication of the position or status of the item back to the optoelectronics module.

3.1.10 steady-state supply voltage—an input voltage that does not deviate from a specified nominal tolerance (ex: ±5 %).

3.1.11 tether valve limit switch—a limit switch used to detect valve position via a tether line connected to the valve handle.

3.1.12 transient supply voltage—a voltage superimposed on the steady-state supply voltage that is greater than the specified steady-state tolerance and has a very rapid rise and fall.

4. Classification

4.1 Designation—Most switch manufacturers use designations, systematic numbering or identifying codes. Once understood, these designations could aid the purchaser in quickly identifying the switch type, electrical power ratings, and other characteristics.
4.2 Design—Fiber-optic position switches typically consist of an assembly with three major components: optical sensor head, fiber-optic cables, and optoelectronics module. The optoelectronics module shall be interchangeable between any of the sensor types.

4.3 Types—The following are common types of fiber-optic position switches:

   - Proximity
   - Limit, pin actuated
   - Limit, lever actuated
   - Limit, lever and roller
   - Limit, tether valve

4.3.1 Fiber-Optic Proximity Switches—The fiber-optic proximity switch sensor head receives the light beam from the light source in the optoelectronics module via a fiber-optic cable. The sensor head emits the light beam to detect an object in a specific location. The sensor head also receives the light beam reflection from the object, typically via a wide angle receiving lens, and is detected by the light beam receiving device in the optoelectronics module. When the object moves into the sensing site, the light beam is reflected into the receiving lens completing the fiber-optic light path. It is important to consider contrasting light levels between reflections from background objects when no object to be detected is present and reflections from the object to be detected, when selecting a fiber-optic proximity switch.

4.3.2 Fiber-Optic Limit Switches—The fiber-optic limit switch sensor head houses the mechanical contact device that senses the position of the object to be detected. The mechanical contact device is typically a pin or plunger, lever, roller, lever and roller, or tether valve. The fiber-optic limit switch sensor head receives the light beam from the light source in the optoelectronics module via a fiber-optic cable. The same fiber-optic cable allows completion of the light path to a fiber-optic receiver in the optoelectronics module. Dependent upon the configuration of the switch, the mechanical contact device either completes or breaks the light path upon detection of the object.

5. Ordering Information

5.1 The purchaser should provide the manufacturer with all of the pertinent application data. Recommended data is shown in 5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they should also be described.

5.2 Acquisition Requirements—Acquisition documents should specify the following:

   - Title, number, and date of this specification,
   - Manufacturer’s part number,
   - Switch type required (see 4.3),
   - Unique or special enclosure requirements (see 7.1),
   - Type of optoelectronics module (see 7.2). If control enclosure or console mounted, specify requirements,
   - Length of fiber-optic cable required,
   - Type of electrical connection (see 7.4),
   - When the electrical connection mating plug is not to be provided (see 7.4),
   - System operating characteristics,
   - Materials,
   - Environmental requirements,
   - Quantity of switches required,
   - Size and weight restrictions (see 7.5),
   - Critical service life requirements (see 8.1),
   - Performance requirements (see 8.2),
   - Special surface finish requirements (see 9.1),
   - Special workmanship requirements (see 9.2),
   - When certification is required (see 13),
   - Special marking requirements (see 14),
   - Special packaging or package marking requirements (see 15),
   - When ISO 9001 quality assurance system is not required (see 16.1), and
   - Special warranty requirements (see 16.1).

6. Materials and Manufacture

6.1 Position Switches—Materials for the fiber-optic position switches shall be corrosion resistant and noncombustible or fire retardant.

7. Physical Properties

7.1 Enclosure—If case sealing is required, the mechanism, materials, and process shall be described. The same should apply to the electrical connector. Resistance to cleaning solvents should likewise be stated. Unique or special enclosure requirements shall be specified in the acquisition requirements (see 5.2).

7.2 Optoelectronics Module—The optoelectronics module shall contain the optical and signal conditioner devices necessary to convert the sensor head output to the specified electrical output. Optoelectronics modules shall be designed in consideration of their mounting method (type): bulkhead mounted, control enclosure mounted, or console mounted (microprocessor expansion card).

7.3 External Configuration—The outline drawing shall show the configuration with dimensions in SI units (inch-pound units) if they are not specified. The outline drawing shall include limiting dimensions for electrical and fiber-optic connections if they are not specified. The outline drawing shall indicate the mounting method with hole size, center location, and other pertinent dimensions. Where threaded holes are used, thread specifications shall be provided.

7.4 Electrical Connection—An electrical interface connector receptacle and mating plug shall be provided with each optoelectronics module of the position switch unless otherwise specified in the acquisition requirements (see 5.2). Other possible electrical interface connections include pigtails and terminal boards.

7.5 Size and Weight—The purchaser may have intended applications in which size and weight are limited. Size and weight restrictions shall be specified in the acquisition requirements (see 5.2).

8. Performance Requirements

8.1 Service Life—The purchaser may have a minimum specified service life requirement that may be critical. Critical service life requirements shall be specified in the acquisition requirements (see 5.2).
8.2 Switch Performance—Critical performance requirements shall be specified in the acquisition requirements (see 5.2). The following performance characteristics and environmental exposures may or may not be important to each purchaser’s intended application.

(a) Warm-up time,
(b) Steady-state supply voltage and frequency (ac),
(c) Steady-state supply voltage (dc),
(d) Response time,
(e) Transient supply voltage and frequency (ac),
(f) Transient supply voltage (dc),
(g) Change in optical transmittance,
(h) Dynamic range,
(i) Ambient light susceptibility,
(j) Temperature,
(k) Humidity,
(l) Salt spray,
(m) Insulation resistance,
(n) Power interruption,
(o) Short circuit,
(p) Line voltage reversal (dc powered),
(q) Output,
(r) Mechanical life,
(s) Enclosure,
(t) Vibration,
(u) Shock,
(v) Electromagnetic interference (EMI), and
(w) Power system harmonic distortion.

9. Workmanship, Finish and Appearance

9.1 Finish and Appearance—Any special surface finish and appearance requirements shall be specified in the acquisition requirements (see 5.2).

9.2 Workmanship—Any special workmanship requirements shall be specified in the acquisition requirements (see 5.2).

10. Number of Tests and Retests

10.1 The number of test specimens to be subjected to first-article and conformance tests shall be specified and should depend on the fiber-optic position switch design. As guidance, for each switch covered by a separate and distinct design, a test specimen for each design should require testing. In instances in which a singular design series may cover multiple switch configurations, a minimum of three test specimens should be tested, provided the electrical, optical, and mechanical similarities are approved by the purchaser. It is recommended that one unit be tested for each switch configuration regardless of design similarity.

11. Inspection

11.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

(a) First-article tests (see 11.2)
(b) Conformance tests (see 11.3)

11.2 First-Article Tests—First-article test requirements shall be specified, where applicable. First-article test methods should be identified for each design and performance characteristic specified.

11.3 Conformance Tests—Conformance testing is accomplished when first-article tests were satisfied by a previous acquisition or the product has demonstrated reliability in similar applications. Conformance tests are usually less intensive than first-article tests, often verifying that samples of a production lot meet a few critical performance requirements.

12. Test Data

12.1 Test Data—Test data shall remain on file at the manufacturer’s facility for review by the purchaser upon request. It is recommended that test data be retained in the manufacturer’s files for at least three years or a period of time acceptable to the purchaser and manufacturer.

13. Certification

13.1 When specified in the acquisition requirements (see 5.2), the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

14. Product Marking

14.1 Special purchaser specified product marking shall be listed in the acquisition requirements (see 5.2). The minimum data to be clearly marked on each switch shall include the following:

14.1.1 Sensor Head:

(a) “FIBER-OPTIC POSITIONS SWITCH—SENSOR HEAD,”
(b) Manufacturer’s name,
(c) Manufacturer’s serial number or lot number, and
(d) Manufacturer’s part number.

14.1.2 Optoelectronics Module:

(a) “FIBER-OPTIC POSITIONS SWITCH—OPTOELECTRONICS MODULE”
(b) Manufacturer’s name,
(c) Manufacturer’s serial number or lot number,
(d) Manufacturer’s part number, and
(e) Excitation voltage.

15. Packaging and Package Marking

15.1 Packaging of Product for Delivery—Product should be packaged and marked for shipment in accordance with Practice D 3951.

15.2 Special packaging or package marking requirements for shipment or storage shall be identified in the acquisition requirements (see 5.2).

16. Quality Assurance

16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see 5.2).

16.2 Responsibility for Warranty—Unless otherwise specified, the manufacturer is responsible for the following:

(a) All materials used to produce a unit and
(b) Workmanship to produce the unit.

Special warranty requirements shall be specified in the acquisition requirements (see 5.2).
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard F25(FOSW)M-99 and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supersedes MIL-S-24798, Switch, Position, Proximity (Non-Contact) or Limit (Mechanical Contact), Fiber Optic, for new ship construction.

S1. SWITCH, POSITION, PROXIMITY (NONCONTACT) OR LIMIT (MECHANICAL CONTACT), FIBER-OPTIC

S1.1 Scope
S1.1.1 This specification supplement covers the requirements for fiber-optic position switches (proximity and limit) designed to meet the requirements for use onboard naval ships. This specification does not include switches that transfer an optical signal from one path to another by an external force or energy applied to the switch.
S1.1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only.

S1.2 Referenced Documents
S1.2.1 ASTM Standards:
- D 542 Test Methods for Index of Refraction of Transparent Organic Plastics
- D 570 Test Method for Water Absorption of Plastics
S1.2.2 EIA Standards:
- 455-20 FOTP-20 Measurement of Change in Optical Transmittance
- 455-22 FOTP-22 Ambient Light Susceptibility of Fiber Optic Components
- 455-34 FOTP-34 Interconnection Device Insertion Loss Test
S1.2.3 NEMA Standards:
- 250 Enclosures for Electrical Equipment (1000 Volts Maximum)
S1.2.4 Military Standards
- MIL-C-83522 Connectors, Fiber Optic, Single Terminus, General Specification for
- MIL-C-83522/16 Connector, Fiber Optic, Single Terminus, Plug, Adapter Style, 2.5 Millimeter Bayonet Coupling, Epoxy
- MIL-C-83522/17 Connector, Fiber Optic, Single Terminus, Adapter, 2.5 Millimeter Bayonet Coupling, Bulkhead Panel Mount

S1.3 Terminology
S1.3.1 Terminology is consistent with that of Section 3 and the referenced documents.

S1.4 Designation
S1.4.1 Designation—For this specification, fiber-optic position switch designations shall be assigned as specified in S1.5.2 and listed in the format below:

Example: F25(FOSW)M-1-B-DC

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type</th>
<th>Optoelectronics Module</th>
<th>Power Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>F25(FOSW)M-99</td>
<td>1</td>
<td>B</td>
<td>DC</td>
</tr>
<tr>
<td>S1.4.2</td>
<td></td>
<td>S1.4.3</td>
<td>S1.4.4</td>
</tr>
</tbody>
</table>

S1.4.2 Type—The following designators have been established for the various types of fiber-optic position switches:
1—Proximity position switch sensor head,
2—Pin-actuated limit position switch sensor head,
3—Lever-actuated limit position switch sensor head,
4—Lever and roller limit position switch sensor head,
5—Tether valve limit position switch sensor head,
6—Special (see S1.5.2).

S1.4.3 Optoelectronics Module—The optoelectronics module shall be designated as follows:
A—Bulkhead mounted,
B—Control enclosure mounted, and
C—Console mounted (microprocessor or programmable logic controller expansion card).

S1.4.4 Electrical Power Supply—The electrical interface wiring shall be determined by the power supply as follows:
S1.5 Ordering Information
S1.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data shown in accordance with S1.5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S1.5.2 Acquisition Requirements—Acquisition documents shall specify the following:
(a) Title, number, and date of this specification;
(b) Part designation (see S1.4.1);
(c) Special type position switch (see S1.4.2) description and unique requirements;
(d) National Stock Number (NSN) if available;
(e) Sensor head mounting requirements (see S1.7.2);
(f) Requirements when Type B or Type C optoelectronics module is specified (see S1.7.3.2 and S1.7.3.3);
(g) Optoelectronics module mounting method if other than specified herein (see S1.7.3);
(h) Type of fiber-optic connectors, receptacles, and bulkhead adapters, if other than specified herein (see S1.7.4);
(i) Fiber-optic cable length required (see S1.7.6);
(j) Critical dimensions of the switch (see S1.7.13);
(k) Quantity of switches required;
(l) When first-article tests are required (see S1.12.2);
(m) Special marking requirements (see S1.14);
(n) Special packaging or package marking requirements (see S1.15); and
(o) Special warranty requirements (see S1.16.1).

S1.5.3 First-Article Tests—The purchaser should include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article inspection to those manufacturers offering a product which has been previously acquired or tested by the purchaser, and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S1.6 Materials
S1.6.1 Metals—Unless otherwise specified herein, all metals used in the construction of the proximity or limit position switch shall be corrosion resistant. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion.

S1.6.2 Flammable Materials—Materials used in the construction of the proximity or limit position switch shall be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application. Fire-retardant additives may be used provided they do not adversely affect the specified performance requirements of the basic materials. Fire retardance shall not be achieved by use of nonpermanent additives to the basic material.

S1.6.3 Fungus-Resistant Materials—Materials used in construction of the switch sensor head and optoelectronics module shall not support the growth of fungus.

S1.6.4 Solvents, Adhesives, and Cleaning Agents—When chemicals or cements are used in bonding of internal proximity or limit position switch components, no degradation shall result during in-service use.

S1.6.5 Refractive Index Matching Gels, Fluids, or Compounds—Refractive index matching gels, fluids, or compounds shall not produce toxic, corrosive, or explosive byproducts. The material is subject to a toxicological data and formulations review and inspection, for safety of material, by the purchaser. The index matching material shall be either silicone or aliphatic hydrocarbon material and shall be clear and transparent. The index matching material shall have an index of refraction of 1.46 ± 0.01 as tested in accordance with Test Methods D 542, when exposed to operating temperature extremes between −28°C and +85°C. The index matching material shall not flow at elevated temperatures. The index matching material shall remain clear and transparent when tested for water absorption in accordance with Test Method D 570. The index matching material shall have a shelf life not less than 36 months at 25°C ± 5°C. The 36-month period commences on the date of adhesive manufacture.

S1.7 Physical Properties
S1.7.1 Design and Construction—The switch shall consist of an assembly with three major components: optical sensor head, fiber-optic cable, and optoelectronics module. The optoelectronics module shall be interchangeable between any of the sensor head types (see S1.4.2).

S1.7.2 Sensor Head—The sensor head shall meet the requirements specified herein. Sensor head mounting requirements shall be as required for the switch application and specified in the acquisition requirements (see S1.5.2). It is recommended that the sensor head be installed such that sufficient clearance is provided for repair and maintenance of the unit.

S1.7.3 Optoelectronics Module—The optoelectronics module shall contain the optical and signal conditioner devices necessary to convert the sensor head output to the specified electrical output. The module shall be bulkhead mounted, control enclosure mounted, or console mounted as specified in the acquisition requirements (see S1.5.2).

S1.7.3.1 Bulkhead Mounted (Type A)—Bulkhead-mounted optoelectronics modules shall be housed in a junction box. The junction box maximum dimensions shall be 280-mm L by 205-mm W by 130-mm D (11-in. L by 8-in. W by 5-in. D). The junction box material shall be brass. The junction box shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures. The optoelectronics module shall be subjected to all first-article tests as specified (see S1.12.1) before mounting in the junction box.

S1.7.3.2 Control Enclosure Mounted (Type B)—Control enclosure-mounted optoelectronics modules are intended for use within an environmental protective enclosure as part of a
motor controller or other system. The optoelectronics module shall be mounted in an enclosure as specified in the acquisition requirements (see S1.5.2). The optoelectronics module shall be subjected to all first-article tests as specified (see S1.12.1) before mounting in the enclosure.

S1.7.3.3 Console Mounted (Type C)—Console-mounted (microprocessor or programmable logic controller (PLC) expansion card) optoelectronics modules are intended for use as a plug-in card for a console control system. The optoelectronics module shall be packaged in a console-mounted circuit card as specified in the acquisition requirements (see S1.5.2). The size, weight, pinout configuration, and number of channels shall be as specified in the acquisition requirements (see S1.5.2).

S1.7.4 Fiber-Optic Cable—A fiber-optic cable shall be used to connect sensor head to the optoelectronics module. There shall be no less than two times the number of fibers needed for operation of the switch in the cable. Penetration of the fiber-optic cable into the sensor head and the optoelectronics module shall be watertight. The required length of cable shall be as specified in acquisition requirements (see S1.5.2).

S1.7.5 Optical Fiber—All optical fiber used in the construction of the fiber-optic switch shall be in accordance with MIL-PRF-49291.

S1.7.6 Fiber-Optic Connectors, Receptacles, and Bulkhead Adapters—All fiber-optic connectors, receptacles, and bulkhead adapters shall be in accordance with MIL-C-83522 and MIL-C-83522/16, 17, and 18, respectively, or equal. Connectors shall be assembled at both ends of the fiber-optic cable between the sensor head and the optoelectronics module.

S1.7.7 Local Status Indication—The switch optoelectronics module shall have three indicator light-emitting diodes (LEDs): (1) a green LED that indicates the switch is closed when illuminated, (2) a red LED that indicates the switch is open when illuminated, and (3) a yellow LED that indicates a switch is closed with alarm level condition when illuminated. The LEDs shall be located on either the top or front of the module as it would be mounted during usage. The LEDs shall be visible in fluorescent room lighting. One LED and only one LED shall be lit at all times when the optoelectronics unit is energized.

S1.7.8 Low-Intensity Alarm Set Point Adjustment—The switch shall provide an indication of a degradation in the intensity of the transmitted optical signal via an alarm output. The optoelectronics module shall provide a means for adjusting the low-intensity alarm set point by one individual and without the necessity for an electrical disconnection. The low-intensity alarm set point adjustments shall be labeled and shall be accessible when the optoelectronics enclosure cover (for mounting Type A and Type B) is removed. The low-intensity alarm level set point shall allow tamperproof sensitivity adjustment over the entire dynamic range of the optoelectronics module. The optoelectronics module low-intensity alarm shall allow for an indication that maintenance is required before a false open switch indication.

S1.7.9 Electrical Overload Protection and Isolation—The optoelectronics module shall be provided with overload and short circuit protection. As a minimum, ac switches shall be protected from continuous overloads up to 6-A rms. Interruption of the operating voltage shall be required to restore normal operation of the switch after an overload has been detected. A means of isolating the optoelectronics module from ship power shall be provided on the unit.

S1.7.10 Wire Colors:

S1.7.10.1 ac Switches—Wire colors shall be as follows:

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>= input</td>
</tr>
<tr>
<td>White</td>
<td>= output</td>
</tr>
<tr>
<td>Red</td>
<td>= normally open (N.O.) output</td>
</tr>
<tr>
<td>Green</td>
<td>= dc power high (positive lead)</td>
</tr>
<tr>
<td>White</td>
<td>= normally closed (N.C.) output</td>
</tr>
<tr>
<td>Black</td>
<td>= dc power low (negative lead)</td>
</tr>
</tbody>
</table>

S1.7.11 Lubrication—The fiber-optic position switch shall not require lubrication.

S1.7.12 Weight—The weight of the fiber-optic position switch shall not exceed 4.5 kg (10 lb).

S1.7.13 Dimensions—The critical dimensions of the fiber-optic position switch shall be as specified in the acquisition requirements (see S1.5.2).

S1.8 Performance Requirements

S1.8.1 Reliability—The fiber-optic position switch shall be constructed for a service life of no less than 40 000 h.

S1.8.1.1 Switch Electrical Characteristics—Fiber-optic position switches shall operate on either ac or dc power as specified in the part designation (see S1.5.2)

S1.8.2 ac Switch Electrical Characteristics—ac switches shall be two-wire devices and shall operate in series with the load. ac switches shall be selectable between normally open or normally closed configuration.

S1.8.2.1 Operating Voltage—The switch shall be designed to operate using 115-V, 60-Hz, single-phase, ungrounded, ac power as defined in MIL-STD-1399, Section 300. The switch shall operate with power supply variations as specified in S1.11.9 and S1.11.10. Full-time surge protection shall be provided for power supply limits.

S1.8.2.2 Voltage Drop—The voltage drop across each switch during the activated (ON) state shall not be greater than 4-Vac root mean square (rms) at rated load current.

S1.8.2.3 Leakage Current—The leakage current through each switch during the deactivated (OFF) state shall not be greater than 2-mA rms.

S1.8.2.4 Load Ratings—The switch load ratings shall be as specified in S1.8.2.5 through S1.8.2.7.

S1.8.2.5 Resistive—The switch shall have a resistive rating of 1.25.

S1.8.2.6 Inductive—The switch shall operate inductive loads with a power factor between 1 and 0.35. As a minimum, the switch shall have a make-current rating of 10-A rms for three cycles of the specified operating voltage and a break current rating of 1.25-A rms.

S1.8.2.7 Minimum Load—The switch shall operate with a minimum load of 15-mA rms.

S1.8.3 Multiple ac Switch Operation:

S1.8.3.1 Series Connection—When two ac switches of the same designation (see S1.4.1) are operated in series, the total...
switch voltage drop at the load shall not be greater than 8-Vac rms at the rated load current.

S1.8.3.2 Parallel Connection—When two ac switches of the same designation (see S1.4.1) are operated in parallel, the total switch leakage current at the load shall not be greater than 4-mA rms.

S1.8.4 dc Switch Electrical Characteristics—dc switches shall be four-wire devices and shall operate as voltage sources. Switches shall be line powered and shall have solid-state outputs. Each switch shall have one normally open (N.O.) and one normally closed (N.C.) output in a complementary configuration. The total power drawn from the line shall not be greater than the sum of 50 mA plus the output load current.

S1.8.4.1 Operating Voltage—The switch shall be designed to operate using 28 ± 4.5 V. The switch shall operate with power supply variations as specified in S1.11.9 and S1.11.10. Full-time surge protection shall be provided for power supply limits.

S1.8.4.2 Voltage Drop—The voltage drop across each switch during the activated (ON) state shall not be greater than 1.5 Vdc at rated load current.

S1.8.4.3 Leakage Current—Leakage current from each output in the open (OFF) state shall not be greater than 300 µA with 35 Vdc applied to the switch.

S1.8.5.4 Load Ratings—The switch load ratings shall be as specified in S1.8.5.5 through S1.8.5.6.

S1.8.5.5 Maximum Current—The switches shall operate continuously and supply 250 mA to resistive and inductive loads and 100 mA into lamp loads. The inductive load shall have a decay time of not greater than 100 ms when the load is interrupted. This decay shall be measured from the 90 % level to the 10 % level.

S1.8.5.6 Minimum Load—The switches shall supply any load current from maximum (see S1.8.5.5) down to zero.

S1.8.5 Multiple dc Switch Operation:

S1.8.5.1 Series Connection—When two dc switches of the same designation (see S1.4.1) are operated in series, the total switch voltage drop at the load shall not be greater than 3 Vdc at the rated load current.

S1.8.5.2 Parallel Connection—When two dc switches of the same designation (see S1.4.1) are operated in parallel, the total switch leakage current at the load shall not be greater than 600 µA.

S1.8.6 Switch Performance:

S1.8.6.1 Operation—The switch shall operate as specified in S1.7.7, S1.7.8 and S1.8.1.1.

S1.8.6.2 Response Time—Response time is the time it takes to go from 10 to 90 % of full rise. The response time of the opto-electronics module shall be no greater than 100 ms closed to open and 100 ms open to closed.

S1.8.6.3 Warm-Up Time—The switch shall operate properly as specified in S1.7.7 and S1.8.1.1 within 1 min.

S1.8.6.4 Change in Optical Transmittance—Changes in optical transmittance shall not be greater than 3 dB.

S1.8.6.5 Dynamic Range—The dynamic range of the optoelectronics module shall not be less than 30 dB.

S1.8.6.6 Ambient Light Susceptibility—The switch shall not indicate a false closed condition when the switch is open nor a false open condition when the switch is closed in the presence of ambient light.

S1.8.6.7 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The switch shall perform in accordance with S1.8.6.1 and shall not indicate a false open condition when the switch is closed, nor shall it indicate a false closed condition when the switch is open, when operated within the limits of steady-state voltage.

S1.8.6.8 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The switch shall perform in accordance with S1.8.6.1 and shall not indicate an open switch condition at any time when exposed to the specified limits of transient voltage and frequency.

S1.8.6.9 Insulation Resistance—The insulation resistance of the optoelectronics module shall not be less than 10 MΩ.

S1.8.6.10 Power Interruption—The switch shall perform in accordance with S1.8.6.1 and shall not indicate an open switch condition during steady-state operation when exposed to repeated power interruptions.

S1.8.6.11 Short Circuit—The switch shall perform in accordance with S1.8.6.1 and the local status indication shall indicate the correct switch position when experiencing a shorted output circuit.

S1.8.6.12 Line Voltage Reversal (dc Switch Only)—The switch shall operate in accordance with S1.8.6.1 after the input power leads have been reversed.

S1.8.6.13 Mechanical Life—The switch shall operate in accordance with S1.8.6.1 and S1.8.6.4 for a minimum of 260 000 cycles. The switch shall show no evidence of physical damage.

S1.8.6.14 Temperature—The sensor head and optoelectronics module shall operate within the optical limits specified in S1.8.6.4 when exposed to the specified temperature limits. The switch shall show no evidence of physical damage.

S1.8.6.15 Enclosure—The sensor head and optoelectronics module shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S1.8.6.16 Vibration—The sensor head and optoelectronics module shall meet the requirements of S1.8.6.1 and S1.8.6.4 when exposed to vibration in accordance with MIL-STD-167-1. The switch shall show no evidence of physical damage.

S1.8.6.17 Shock—The switch shall operate within the requirements of S1.8.6.1 and S1.8.6.4 when exposed to shock in accordance with MIL-S-901. Minor deformation of the switch is acceptable provided the sensor operates in accordance with S1.8.6.1 after shock. The switch shall not indicate a change in state for greater than 50 ms during shock.

S1.8.6.18 Electromagnetic Interference (EMI)—The switch shall perform within the limits of S1.8.6.1 and S1.8.6.4 and shall not indicate a change in state at any time when exposed to EMI in accordance with MIL-STD-461 Table II, except as modified below:

CE101—The test signal shall be applied only to the ac power leads of the test sample.

CE102—The test signal shall be applied only to the ac power leads of the test sample.
CS114—Only Limit Curve No. 2 shall apply with the frequency range limited to 10 kHz to 30 MHz.
RE101—Only the limit curve for 50 cm shall apply.
RS103—The frequency range shall be limited to 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

S1.9 Workmanship, Finish, and Appearance
S1.9.1 Surface Finish—Surfaces of castings, forgings, molded parts, stampings, and machined and welded parts shall be free of defects such as cracks, pores, undercuts, voids, and gaps, as well as harmful or extraneous materials such as sand, dirt, fins, sharp edges, scale, and flux. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn through, warpage, or dimensional change as a result of heat from welding. There shall be no damage to adjacent parts resulting from welding.

S1.10 Number of Tests and Retests
S1.10.1 First-Article Test Sample Size—A sample shall consist of a sensor head (Type 1 through 5), an optoelectronics module, associated fiber-optic cable, connectors, bulkhead adapters, and connector receptacles. Four samples of the same test lot (see S1.10.1.1) shall be subjected to first-article tests. Each sample shall be supplied with the length of cable required for the application (see S1.5.2) or 30 m of fiber-optic cable, whichever is greater. Note that two items will be tested at the same time: the optoelectronics module and the sensor head, whether proximity or limit. Prior testing of an optoelectronics module in conjunction with the testing of a different sensor head does not exclude the optoelectronics module from any of the testing requirements specified herein. Three samples shall be subjected to the tests of Group I and one sample shall be subjected to the tests of Group II.

S1.10.1.1 First-Article Test Lot—A test lot shall consist of all fiber-optic switches of the same classification (see S1.4.1), produced under essentially the same conditions, in the same facility from the same materials and offered for delivery at the same time.

S1.10.2 Conformance Test Sample Size—Fiber-optic switches offered for delivery shall be subjected to Group A tests listed in Table S1.1. The number of samples subjected to Group B tests shall be in accordance with Table S1.2.

S1.11 Test Methods
S1.11.1 Test Conditions—Except where the following factors are the variables, the tests specified in S1.11.2 shall be conducted with the equipment under the following operating environmental conditions:

<table>
<thead>
<tr>
<th>TABLE S1.1 Conformance Tests</th>
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</thead>
<tbody>
<tr>
<td><strong>Test</strong></td>
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<td>General examination</td>
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<tr>
<td>Operation</td>
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<td>Response time</td>
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<td>Dynamic range</td>
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<tr>
<td>Supply voltage and frequency (steady-state)</td>
</tr>
<tr>
<td>Insulation resistance</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Enclosure</td>
</tr>
</tbody>
</table>

(a) Ambient temperature shall be 23 ± 2°C.
(b) Relative humidity shall be ambient.

S1.11.2 Tests—Except for the warm-up time test (see S1.11.5), the switch and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S1.11.3 Operation—The operation of the sensor head and optoelectronics module shall be tested by manually opening and closing the switch for ten cycles. Performance shall be in accordance with S1.8.6.1.

S1.11.4 Response Time—The response time shall be measured by opening and closing the switch via a beam gate, controlled by a function generator. The output of the switch shall be connected to a calibrated optical oscilloscope or a calibrated electrical oscilloscope as appropriate. The output from the function generator shall be connected to the monitoring oscilloscope and the traces shall be compared to determine the response time of the system. Performance shall be in accordance with S1.8.6.2.

S1.11.5 Warm-Up Time—The switch shall be deenergized for a period of not less than 12 h. The switch shall then be energized. The warm-up time is the elapsed time between the application of line power and the point at which the switch output reaches the conditions specified in S1.8.6.3. Performance shall be in accordance with S1.8.6.3.

S1.11.6 Change in Optical Transmittance—The change in optical transmittance of the sensor head shall be performed in accordance with EIA 455-20. Performance shall be in accordance with S1.8.6.4.

S1.11.7 Dynamic Range—A calibrated optical attenuator with two jumpers shall be tested for insertion loss in accordance with EIA 455-34. The attenuator shall then be connected to the transmitter and receiver via the two jumper cables. The attenuation shall be increased from 0 dB (plus insertion loss of attenuator and jumpers) to 50 dB (plus insertion loss of attenuator and jumpers). The switch shall be left in the open position. The dynamic range will be exceeded when the switch indicates a closed switch position. The dynamic range shall be in accordance with S1.8.6.5.

S1.11.8 Ambient Light Susceptibility—The ambient light source and general test conditions shall be in accordance with EIA 455-22. The entire switch shall be placed in the beam of the light source and placed in a closed condition. After a period of 10 min, the switch shall be placed in an open condition by disconnecting the optical cable from the source. The switch...
shall then be subjected to the ambient light source for an additional 10 min. Performance shall be in accordance with S1.8.6.6.

S1.11.9 Steady-State Supply Voltage and Frequency (ac) and Supply Voltage (dc)—The switch shall be operated for not less than 15 min and shall be manually opened and closed not less than ten times at conditions of nominal, maximum, and minimum steady-state voltages (dc) and all possible combinations of nominal, maximum, and minimum steady-state voltages and frequencies (ac). Each of the conditions shall be tested at 0 ± 2°C, 25 ± 2°C, and 60 ± 2°C. This test may be performed in conjunction with the temperature test (see S1.11.18). The switch shall be allowed to stabilize at each testing temperature before the steady-state voltage and frequency test shall be performed. Performance shall be in accordance with S1.8.6.7.

S1.11.10 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The switch shall be tested to S1.11.11 (ac) or S1.11.12 (dc). The switch shall be placed in a closed switch position and the output of the switch shall be monitored throughout the test. Performance shall be in accordance with S1.8.6.8.

S1.11.11 Transient Supply Voltage and Frequency (ac)—The test shall be performed as follows:
(a) With the switch operating at steady-state voltage of 123 Vac, the voltage shall be increased to 138 Vac, and then decreased back to the steady-state voltage of 123 Vac in a 2-s period.
(b) With the switch operating at a steady-state voltage of 107 Vac, the voltage shall be decreased to 92 Vac, and then increased back to the steady-state voltage of 107 Vac in a 2-s period.
(c) With the switch operating at a steady-state frequency of 62 Hz, the frequency shall be increased to 63.5 Hz, and then decreased back to the steady-state frequency of 62 Hz in a 2-s period.
(d) With the switch operating at a steady-state frequency of 58 Hz, the frequency shall be decreased to 56.5 Hz, and then increased back to the steady-state frequency of 58 Hz in a 2-s period.

S1.11.12 Transient Supply Voltage (dc)—The test shall be performed as follows:
(a) With the switch operating at a steady-state voltage of 32.5 Vdc, the voltage shall be increased to 34.5 Vdc, and then decreased back to the steady-state voltage of 32.5 Vdc in a 2-s period.
(b) With the switch operating at a steady-state voltage of 23.5 Vdc, the voltage shall be decreased to 21.5 Vdc, and then increased back to the steady-state voltage of 23.5 Vdc in a 2-s period.

S1.11.13 Insulation Resistance—The insulation resistance of the optoelectronics module shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The temperature shall be 25 ± 5°C and the relative humidity shall be 50 ± 10%.

requirements (see S1.8.6.9) and is steady or increasing, the test may be terminated before the end of the 2-min period. Performance shall be in accordance with S1.8.6.9.

S1.11.14 Power Interruption—The switch shall be placed in a closed switch position and the output of the switch shall be monitored throughout the test. With the switch operating within the steady-state tolerances of voltage and frequency, the external power supply shall be suddenly interrupted, and after an interval between 3 and 4 s, the power supply shall be reestablished to within the steady-state tolerances. After the switch has been operated long enough to detect any major performance degradation, the power shall be interrupted for an interval of 30 s. This cycle (3- to 4-s interruption, monitor, then 30-s interruption) shall be repeated three times (total of four). Performance shall be in accordance with S1.8.6.10.

S1.11.15 Short Circuit—The switch shall be deenergized. The electrical output leads or terminals of the optoelectronics module shall be connected directly together with no load resistance. The switch shall be energized for 5 min. The switch shall be manually opened and closed ten times during this period. Immediately following the 5-min period, the output pins shall be unshorted. Performance shall be in accordance with S1.8.6.11.

S1.11.16 Line Voltage Reversal (dc)—The switch power supply shall be connected as follows: the positive 28-Vdc signal shall be applied to connector Pin “B.” The dc reference signal shall be applied to connector Pin “A.” The power supply shall be energized for a period of 10 min and shall then be disconnected. The power supply shall then be correctly applied (Pin “A” positive, Pin “B” negative). Performance shall be in accordance with S1.8.6.12.

S1.11.17 Mechanical Life—The switch shall be placed in the closed switch condition. The switch shall then be operated for 260 000 cycles (open-close is one cycle). The cycle rate shall be between one cycle per s and one cycle every 2 s (1 to 0.5 Hz). A change in optical transmittance test (see S1.11.6) shall be performed at the end of the mechanical life test. Performance shall be in accordance with S1.8.6.13.

S1.11.18 Temperature—The mated cable to switch assemblies shall be tested at high and low temperature as specified herein. The switch shall be placed in a closed switch position and Steps 1 through 6 shall be performed. The switch shall then be placed in an open switch position and Steps 1 through 6 shall be performed. Change in optical transmittance shall be measured in accordance with S1.11.6. Visual inspection shall be performed after the test. Performance shall be in accordance with S1.8.6.14.

Step 1—Hold temperature at room ambient (25 ± 2°C) for one h.
Step 2—Decrease temperature in steps of 10°C at 30 min per step until −28 ± 2°C is achieved.
Step 3—Hold temperature at −28 ± 2°C for 24 h.
Step 4—Increase temperature in steps of 10°C at 30 min per step until 65 ± 2°C is achieved.
Step 5—Hold temperature at 65 ± 2°C for 24 h.
Step 6—Decrease temperature in steps of 10°C at 30 min per step until 25 ± 2°C is achieved.
S1.11.19 Enclosure—The sensor head and optoelectronics module shall be subjected to the tests in NEMA 250 for Type 4X enclosures. Change in optical transmittance shall be measured in accordance with S1.11.6. Performance shall conform to the requirements of S1.8.6.15.

S1.11.20 Vibration—The switch shall be placed in a closed switch position and the output of the switch shall be monitored throughout the test. The switch shall be tested in accordance with MIL-STD-167-1 Type I vibration test. Change in optical transmittance shall be measured in accordance with S1.11.6. Visual inspection shall be performed after the test. Performance shall be in accordance with S1.8.6.16.

S1.11.21 Shock—The switch shall be subjected to the high-impact shock test for Grade A, Type A, Class I, lightweight equipment as specified in MIL-S-901. The switch shall be placed in a closed switch position and the switch shall be monitored throughout the test. The change in optical transmittance shall be measured after each of the nine hammer blows (see S1.11.6). Performance shall be in accordance with S1.8.6.17.

S1.11.22 Electromagnetic Effects—The switch shall be tested in accordance with MIL-STD-461. The switch shall be placed in a closed switch position and the output of the switch shall be monitored throughout the test. Performance shall be in accordance with S1.8.6.18.

S1.12 Inspection

S1.12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:
(a) First-article tests (see S1.12.2).
(b) Conformance tests (see S1.12.3).

S1.12.2 First-Article Tests—When first-article tests are required in the acquisition requirements (see S1.5.2), first-article tests shall be performed before production. First-article tests shall be performed on samples that have been produced with equipment and procedures normally used in production. First-article tests shall consist of the tests specified in Table S1.3. Failure of any switch to meet the requirements of this specification shall be cause for rejection.

### TABLE S1.3 First-Article Tests

<table>
<thead>
<tr>
<th>Operation</th>
<th>Test</th>
<th>Method</th>
<th>Requirement</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td>S1.8.6.1</td>
</tr>
<tr>
<td>Operation</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Response time</td>
<td>S1.11.3</td>
<td>S1.8.6.1</td>
<td></td>
</tr>
<tr>
<td>Warm-up time</td>
<td>S1.11.4</td>
<td>S1.8.6.2</td>
<td></td>
</tr>
<tr>
<td>Change in optical transmittance</td>
<td>S1.11.5</td>
<td>S1.8.6.3</td>
<td></td>
</tr>
<tr>
<td>Dynamic range</td>
<td>S1.11.6</td>
<td>S1.8.6.4</td>
<td></td>
</tr>
<tr>
<td>Ambient light susceptibility</td>
<td>S1.11.7</td>
<td>S1.8.6.5</td>
<td></td>
</tr>
<tr>
<td>Supply voltage and frequency (steady-state)</td>
<td>S1.11.8</td>
<td>S1.8.6.6</td>
<td></td>
</tr>
<tr>
<td>Supply voltage and frequency (transient)</td>
<td>S1.11.9</td>
<td>S1.8.6.7</td>
<td></td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S1.11.10</td>
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<td></td>
</tr>
<tr>
<td>Power interruption</td>
<td>S1.11.11</td>
<td>S1.8.6.9</td>
<td></td>
</tr>
<tr>
<td>Short circuit</td>
<td>S1.11.12</td>
<td>S1.8.6.10</td>
<td></td>
</tr>
<tr>
<td>Line voltage reversal</td>
<td>S1.11.13</td>
<td>S1.8.6.11</td>
<td></td>
</tr>
<tr>
<td>Mechanical life</td>
<td>S1.11.14</td>
<td>S1.8.6.12</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>S1.11.15</td>
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<tr>
<td>Enclosure</td>
<td>S1.11.16</td>
<td>S1.8.6.14</td>
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<tr>
<td>Vibration</td>
<td>S1.11.17</td>
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</tr>
<tr>
<td>Shock</td>
<td>S1.11.18</td>
<td>S1.8.6.16</td>
<td></td>
</tr>
</tbody>
</table>

S1.12.2.1 Order of First-Article Tests—Test specimens shall be subjected to the tests specified in Table S1.13 in the order listed except that the steady-state supply voltage and frequency test may be performed concurrently with the temperature test. Any deviation in the test order shall first be approved by the purchaser.

S1.12.3 Conformance Tests—All switches shall be subjected to conformance tests. Conformance tests shall be in accordance with Table S1.1 and S1.10.2. Failure of any switch to meet the requirements of this specification shall be cause for rejection.

S1.12.4 General Examination—Each fiber-optic position switch shall be examined to determine conformance to the requirements of this specification with respect to material, color, finish, workmanship, safety, construction, assembly, dimensions, weight, identification marking, and label plates. Examination shall be limited to the examinations that may be performed without disassembling the unit in such a manner that its performance, durability, or appearance would be affected. Examination shall include a check of all controls and adjustments, as applicable.

S1.13 Certification

S1.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this standard and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer’s facility for review by purchaser upon request.

S1.14 Product Marking

S1.14.1 Identification Marking—Special purchaser specified product marking shall be listed in the acquisition requirements (see 5.2). Switches shall be permanently and legibly marked. Marking shall be located on the top or front of the sensor head (as mounted in service), and on the top or front of the optoelectronics module (as mounted in service).

S1.14.1.1 Sensor Head—At a minimum, the information specified in 14.1.1 in addition to the following shall be marked on the sensor head:
(a) National stock number (NSN).
(b) Technical manual number, and
(c) Contract number.

S1.14.2 Labeling—Labels with yellow lettering on a black background shall be provided as follows:
S1.14.2.1 Optoelectronics Module—A visible label shall be affixed to the outside of the optoelectronics module cover and shall contain the following:

**WARNING**
UNTERRMINATED OPTICAL CONNECTIONS MAY EMIT LASER RADIATION
DO NOT VIEW BEAM WITH OPTICAL INSTRUMENTS AND AVOID DIRECT EXPOSURE TO THE BEAM
S1.14.2.2 Sensor Head and Inside of Optoelectronics Module—A visible label shall be affixed to the sensor head and the inside of the optoelectronics module and shall contain the following:

WARNING
INVISIBLE LASER RADIATION
AVOID EXPOSURE TO THE BEAM

S1.15 Packaging and Package Marking
S1.15.1 Packaging and package marking shall be in accordance with Section 15.

S1.16 Quality Assurance
S1.16.1 Warranty—Special warranty requirements shall be specified in the acquisition requirements (see S1.5.2).
Standard Specification for Packing, Fiberglass, Braided, Rope, and Wick

This standard is issued under the fixed designation F 2087; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope
1.1 This specification covers the general requirements and tests for braided, rope, and wick fiberglass packing used for boiler, furnace, and other high-temperature equipment seals for service temperatures up to 1000°F (538°C).

2. Referenced Documents
2.1 ASTM Standards:
D 578 Specification for Glass Fiber Strands
D 3951 Practice for Commercial Packaging
D 4268 Test Methods for Testing Fiber Ropes

3. Terminology
3.1 Braided fiberglass—A braid constructed of continuous fiberglass strands.
3.2 Plied—A yarn product produced by twisting together two or more ends of single fiberglass yarns.
3.3 Strand—An ordered assemblage of textile fibers having a high ratio of length to diameter and normally used as a unit, including slivers, rovings, single yarns, plied yarns, cords, braids, ropes, and so forth.
3.4 Yarn—Portion of fiberglass reduced to thread to obtain a fine and thin strand.
3.5 Lot—Unless otherwise specified herein, a lot should consist of all finished packing of one type and size produced in a continuous run or at the same time under essentially the same conditions. The sampling unit should be one spool, reel, or coil of packing as necessary to enable performance of the required examinations or tests.

4. Classification
4.1 Classification—The material shall be of the following types as specified (see 5.1):
Type I—Wick
Type II—Rope
Type III—Braided

5. Ordering Information
5.1 Acquisition Requirements—Acquisition documents must specify the following:
(a) Title, number, and date of this specification;
(b) Type, size, and weight of spool, reel, or coil required (see Section 7);
(c) Marking requirements (see Section 15);
(d) Packaging requirements (see Section 16);
(e) Performance requirements; and
(f) Inspection, testing, and certification of the material should be agreed upon between the purchaser and the supplier as part of the purchase contract (see Sections 12 and 14).

6. Materials and Manufacture
6.1 Material—The material shall be a continuous, high-density-type ETG fiberglass material (see Specification D 578). Asbestos and components containing asbestos are prohibited.
6.2 Construction—The packing shall be composed of twisted plied strands made into a braided packing or laid up into the general form of a wick or a loosely twisted rope according to the manufacturer’s design. If a core is used, it shall be of the same material and construction.

7. Dimensions and Tolerances
7.1 Type I Wick Packing—Unless otherwise specified (see 5.1), the packing shall come in 13-lb (5.9-kg) or 25-lb (11.3-kg) spools, reels, or coils in the sizes listed in Table 1.
7.2 Type II Rope Packing—Unless otherwise specified (see 5.1), the packing shall come in 25-lb (11.3-kg) or 50-lb (22.7-kg) spools, reels, or coils in the sizes listed in Table 2.
7.3 Type III Braided Packing—Unless otherwise specified (see 5.1), the packing shall come in 25-lb (11.3-kg) or 50-lb (22.7-kg) spools, reels, or coils in the sizes listed in Table 3.

8. Workmanship
8.1 Workmanship—The packing should be free from extraneous material and visible defects that may affect its serviceability.
9. Quality Assurance

9.1 Quality Systems—Suppliers shall be prepared to document use of a quality system such as compliance with an ISO 9000 series program or similar program.

10. Specimen Preparation

10.1 Specimen Preparation—Purchaser and supplier should agree on specimen preparation.

11. Test Methods

11.1 Material—Material shall be tested in accordance with Specification D 578.

11.2 Size—Material shall be measured using a flexible measuring tape such as the one described in Test Methods D 4268 and shall be in accordance with the size specified in Table 1, Table 2, or Table 3.

11.3 Splices—Unless otherwise agreed upon, there shall be allowed a maximum of two splices per unit with no piece shorter than 10 ft in length.

11.4 Weight—Material shall be weighed in accordance with Table 1, Table 2, or Table 3 using a weighing scale, accurate to ±0.25 related to the real division of the graduated line. This value is expressed in mass unit of:

(a) the difference between the corresponding values of marks of the graduated line and

(b) the difference between two consecutive indications for digital indication.

12. Inspection and Testing

12.1 Inspection and testing of the material should be agreed upon between the purchaser and the supplier as part of the purchase contract (see 5.1).

13. Rejection

13.1 Materials that fail to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of testing, the producer may make claim for a rehearing or provide for third party testing.

14. Certification

14.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished (see 5.1).

15. Product Marking

15.1 Marking—For commercial shipment, marking should be in accordance with accepted industry practices or as required in the purchase contract (see 5.1).

15.1.1 When specified, a part-numbering system shall be used in accordance with Appendix X1.

16. Packaging

16.1 Commercial Packaging—Commercial packaging should be in accordance with Practice D 3951 or as required in the purchase contract (see 5.1).
X1. PART-NUMBERING SYSTEM

X1.1 Part numbers for fiberglass packing shall include the number of this standard followed by the size shown in Table 1, Table 2 or Table 3. An example of this system is in Fig. X1.1.

![Part-Numbering System Diagram]

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Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Insulated Marine Bulkheads and Decks, Constructed of Steel

1. Scope

1.1 These test methods described in this fire-test response standard are used for determining the fire-test response of insulated marine steel bulkheads and decks. The insulation is either homogeneous or composite construction.

1.2 It is the intent that tests conducted in accordance with these test methods will indicate whether bulkheads and decks will continue to perform their intended function during the period of fire exposure. These test methods shall not be construed as implying suitability for use after fire exposure.

1.3 These test methods prescribe a standard fire exposure for comparing the relative performance of different bulkhead and deck assemblies under controlled laboratory conditions. The application of these test results to predict the performance of actual assemblies when exposed to large pool fires requires a careful engineering evaluation.

1.4 Limitations—These test methods do not provide the following:

1.4.1 Full information on the performance of assemblies constructed with components or of dimensions other than those tested.

1.4.2 An evaluation of the degree to which the assembly contributes to the fire hazard through the generation of smoke, toxic gases, or other products of combustion.

1.4.3 Measurement of flame spread over the surface of the test assembly.

1.4.4 The erosive effect that the velocities or turbulence, or both, generated in large pool fires has on some fire protection materials.

1.4.5 Full information on the performance of assemblies at times less than 5 min because the rise time called out in Section 6 is longer than that of a real fire.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for approximate information only.

1.6 This standard measures and describes the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire-risk assessment of the materials, products, or assemblies under actual fire conditions.

1.7 This test method is based on the fire exposure as defined in Test Methods E 1529 (issued by the Committee on Fire Standards, E05).

1.8 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

E 119 Test Methods for Fire Tests of Building Construction and Materials

E 176 Terminology of Fire Standards

E 511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Gage

E 1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies

3. Terminology

3.1 Definitions of Terms Specific to These Test Methods—Refer to Terminology E 176 for definitions of terms associated with fire issues used in these test methods.

4. Summary of Test Methods

4.1 The fire environment within the furnace shall develop a total heat flux of $204 \pm 6 \text{ kW/m}^2$ ($65000 \pm 5000 \text{ Btu/ft}^2 \cdot \text{h}$) and an average temperature of $1093 \pm 111^\circ \text{C}$ ($2000 \pm 200^\circ \text{F}$) within 5 min from the start of the test. The fire environment shall be controlled by reproducing the furnace temperatures recorded during the furnace calibration method specified in Section 7. This temperature shall be maintained throughout the remainder of the fire test as shown in Fig. 1.

4.2 Performance is defined as the time period during which bulkheads and decks will continue to perform their intended...
5. Significance and Use

5.1 These test methods are intended to provide a basis for evaluating the time period during which bulkheads and decks will continue to perform its intended function when subjected to a controlled, standardized fire exposure.

5.1.1 In particular, the selected standard exposure condition simulates the condition of total continuous engulfment of a member or assembly in the luminous flame (fire plume) area of a large free-burning fluid hydrocarbon pool fire. The standard fire exposure is basically defined in terms of the total flux incident on the test specimen together with appropriate temperature conditions.

5.1.2 It is recognized that the thermodynamic properties of free-burning, hydrocarbon fluid pool fires have not been completely characterized and are variable depending on the conditions, the physical relationship of the structural member to the exposing fire, and other factors. As a result, the exposure specified in these test methods is not necessarily representative of all the conditions that exist in large hydrocarbon pool fires. The specified standard exposure is based upon the best available information and testing technology. It provides a basis for comparing the relative performance of different assemblies under controlled conditions.

5.1.3 It is feasible that substantial changes in the fire performance characteristics of the assembly will result from any variation from the construction or conditions (that is, size, method of assembly, and materials) that are tested.

5.2 The structural assemblies that will be evaluated in accordance with these test methods will be located on a ship.

6. Furnace Control

6.1 The fire environment within the furnace shall develop a total heat flux of 204 ± 16 kW/m² (65 000 ± 5 000 Btu/ft²-h) and an average temperature of 1093 ± 111°C (2000 ± 200°F) within 5 min from the start of the test. The fire environment shall be controlled by reproducing the furnace temperatures recorded during the furnace calibration method specified in Section 7. This temperature shall be maintained throughout the remainder of the fire test as shown in Fig. 1.

6.2 The furnace shall be controlled to maintain the area under the time-temperature curve to within 10% of the corresponding area under the standard time-temperature curve shown in Fig. 1 for fire tests of 60-min or less duration; to within 7.5% for test longer than 60 min but not longer than 120 min; and to within 5% for tests exceeding 120 min in duration. The area under the time-temperature curve shall be obtained by averaging the results of thermocouple readings.

6.3 A correction will be applied for variation of the furnace exposure from the prescribed, where such variation will affect the test results, by multiplying the indicated time period by two thirds of the value obtained by dividing the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period by the area between the standard curve above a baseline of 20°C (68°F) for the same part of the indicated period during the first part of the test. For fire exposure times longer than standard, it is feasible that the indicated rating period will be increased by the amount of the correction, and for fire exposure times less than standard, the indicated rating period may be similarly decreased. The correction will be expressed by the following formula:

\[ C = \frac{2I(A - A_s)}{3(A_s)} \]  

where:

- \( C \) = correction in the same units as \( I \),
- \( I \) = indicated fire-resistance period,
- \( A \) = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period, and
- \( A_s \) = area under the standard furnace curve for the same part of the indicated period.

6.4 The temperature fixed by the furnace calibration (see Section 7) shall be the average temperature obtained from the readings of five thermocouples symmetrically disposed and...
distributed within the test furnace to show the temperature near all parts of the assembly.

6.5 The thermocouples shall be fabricated by fusion-welding the twisted ends of (0.064-in.) diameter (No. 14 B & S gage) chromel-alumel wires having a time constant of 2 min or less, and mounting the wires in porcelain insulators. The thermocouple assembly shall be inserted through a standard weight, nominal 13-mm (½-in.) iron, steel, or inconel pipe, and the end of the pipe from which the welded junction protrudes is to be open. The thermocouple junction shall protrude 13 mm (½ in.) from the open end of the pipe.

6.6 The junction of the thermocouples shall be placed 102 mm (4 in.) away from the exposed face of the test specimen and located at the ½ and ¾ heights of the test specimen.

6.7 Each thermocouple within the furnace shall be recorded at intervals not exceeding 1 min.

7. Calibration of Furnace

7.1 A furnace calibration record shall be maintained and the furnace shall be recalibrated after completion of any repair that could alter the heat generation, retention, or flow characteristics of the furnace.

7.2 The temperature of the furnace shall be measured by five thermocouples. They shall be located as shown in Fig. 2.

7.3 The measured values of all thermocouples and calorimeters shall be recorded at intervals not exceeding 1 min.

7.4 The thermocouples used to measure the temperatures on the face of the calibration wall shall be No. 28 gage, Type K inconel sheathed thermocouples having a time constant of 0.5 s or less. The thermocouple junction shall be located 6.3 mm (¼ in.) from the face of the calibration wall.

7.5 The thermocouples used to measure the temperatures within the furnace shall be constructed as described in 6.5.

7.6 The calorimeters shall have a minimum range from 315 kW/m² (100 000 Btu/ft²·h) and a 180° view angle. They shall be located as shown in Fig. 2.

7.7 The fire environment during the calibration test shall comply with the requirements of 6.1. The length of the calibration test shall be 60 min.

7.8 Individual total heat flux measurements shall lie within the limits shown in Fig. 3.

7.9 The average furnace temperature shall be determined by averaging the temperatures recorded by the five thermocouples placed 102 mm (4 in.) from the specimen. The average shall be 1093 ± 111°C (2000 ± 200°F) and individual temperatures are to be 1093 ± 219°C (2000 ± 400°F) 5 min after the start of the test and until the end of the test.

7.10 The average furnace temperature curve shall be reproduced to maintain the furnace control described in Furnace Control, Section 6.

7.11 A record of the temperatures measured near the face of the wall and the oxygen content shall be retained by the testing laboratory on file for a period of ten years.

8. Furnace Pressure

8.1 A linear pressure gradient exists over the height of furnace, and although the gradient will vary slightly as a function of the furnace temperature, a mean value of 8 Pa/m height shall be assumed in assessing the furnace pressure conditions. The value of the furnace pressure shall be the nominal mean value, disregarding rapid fluctuation of pressure outside the furnace at the same height. It shall be monitored and controlled continuously and by 5 min from the commencement of the test shall be achieved within ±3 Pa, see Fig. 4 for design of the T-shaped sensor.

8.2 For vertically orientated specimens, the furnace should be operated such that a pressure of zero is established at a height of 500 mm above the notional floor level to the test specimen. However, for specimens with a height greater than 3 m, the pressure at the top of the test specimen shall not be greater than 20 Pa, and the height of the neutral pressure axis shall be adjusted accordingly.

8.3 For horizontally orientated specimens, the furnace shall be operated such that a pressure of 20 Pa is established at a position 100 mm below the underside of the specimen.

9. Test Specimen

9.1 Bulkheads:

9.1.1 Dimensions:

9.1.1.1 The minimum overall dimensions for the test specimen including the perimeter details at the top, bottom, and vertical edges, are 2440-mm width and 2500-mm height.

9.1.1.2 The overall dimensions of the structural core shall be 20 mm less in both the width and the height than the overall dimensions of the specimen, and the other dimensions of the structural core shall be as follows:

| Thickness of plating: steel | 4.5 ± 0.5 mm |
| Stiffeners spaced: steel at 600 mm | 65 ± 5 × 65 ± 5 × 6 ± 1 mm |

9.1.1.3 The width of the structural core shall be greater than the specified dimensions providing that the additional width is in increments of 600 mm to maintain the stiffener centers and the relationship between the stiffeners and the perimeter detail.
9.1.1.4 Any joints in the plating shall be full-welded, at least from one side.

9.1.1.5 The construction of a structural steel core having the recommended dimensions is shown in Fig. 5; the thickness of the plating and dimensions of the stiffeners shown are nominal dimensions. Irrespective of the dimensions of the structural core and the material of manufacture, the details around the perimeter shall be as illustrated in Fig. 6.

9.2 Decks:

9.2.1 Dimensions:

9.2.1.1 The minimum overall dimensions for the test specimen including the perimeter details at all edges are 2440 mm in width and 3040 mm in length.

9.2.1.2 The overall dimensions of the structural core shall be 20 mm less in both the width and length than the overall dimensions of the specimen, and the other dimensions of the structural core shall be as follows:

- Thickness of plating: steel 4.5 ± 0.5 mm
- Stiffeners spaced: steel at 600 mm 100 ± 5 × 70 ± 5 × 8 ± 1 mm

9.2.1.3 The width of the structural core shall be greater than the specified dimensions providing that the additional width is in increments of 600 mm to maintain the stiffener center and the relationship between the stiffeners and the perimeter detail.

9.2.1.4 Any joints in the plating shall be full welded, at least from one side.

9.2.1.5 The construction of a structural steel core having the recommended dimensions is shown in Fig. 2; the thickness of the plating and dimensions of the stiffeners shown are nominal dimensions. Irrespective of the dimensions of the structural core and the material of manufacture, the details around the perimeter shall be as illustrated in Fig. 7.

10. Mounting of the Test Specimens

10.1 Restraint and Support Frames:

10.1.1 All test specimens shall be mounted within substantial concrete, or concrete or masonry-lined frames, which are capable of providing a high degree of restraint to the expansion forces generated during the test. The concrete or the masonry shall have a density between 1600 and 2400 kg/m³. The concrete or masonry lining to a steel frame shall have a thickness of at least 50 mm.

10.1.2 The rigidity of the restraint frames shall be evaluated by applying an expansion force of 100 kN within the frame at mid-width between two opposite members of the frame, and measuring the increase in the internal dimensions at these position. This evaluation shall be conducted in the direction of the bulkhead or deck stiffeners, and the increase of the internal dimension shall not exceed 2 mm.

10.2 Bulkheads and Decks:
10.2.1 The structural core to bulkheads and decks shall be fixed into the restraint frame and sealed around its perimeter as shown in Fig. 6. It is feasible that steel spacers, with an approximate thickness of 5 mm, will be inserted between the fixing cleats and the restraint frame if the laboratory finds this necessary.

10.2.2 When the structural core of a bulkhead or a deck is to be exposed to the heating conditions of the test, that is, when the fixing cleats are on the exposed side of the structural core, then a 100-mm-wide perimeter margin adjacent to the restraint frame shall be insulated such that the fixing cleats and the edges of the structural core are protected from direct exposure to the heating condition. In no other situations, irrespective of the type of test specimen, shall the perimeter edges be protected from direct exposure to the heating conditions.

11. Insulating the Test Specimen

11.1 Decks shall be insulated from below on the stiffener side. Insulation shall be on the exposed side.

11.2 For unrestricted use, bulkhead insulation shall be installed on the unexposed side.

11.3 If the insulation is installed on the unstiffened or stiffened exposed side, the use shall be restricted.

11.4 If the insulation is installed on both sides in identical details then the use shall be unrestricted. The unexposed face shall be the stiffened side of the test specimen.

11.5 If different insulation details are installed on both sides of the bulkhead, then the bulkhead shall be tested from both sides for unrestricted use.

12. Conditioning

12.1 General:

12.1.1 The test specimen shall not be tested until it has reached an air-dry condition. This condition is defined as an equilibrium (constant weight) with an ambient atmosphere of 50% relative humidity at 23°C (73°F).

12.1.2 Accelerated conditioning is permissible provided the test method does not alter the properties of component materials. In general, high-temperature conditioning shall be below temperatures critical for the materials.

12.2 Verification—The condition of the test specimen shall be monitored and verified by use of special samples for the determination that shall be so constructed as to materials, as appropriate. These samples shall be so constructed as to represent the loss of water vapor from the specimen by having
similar thicknesses and exposed faces. They shall have minimum linear dimensions of 300 by 300 mm (12 by 12 in.) and a minimum mass of 100 g. Constant weight shall be considered to be reached when two successive weighing operations, carried out at an interval of 24 h, do not differ by more than 0.3 % of the mass of the reference specimen or 0.3 g, whichever is the greater.

12.3 Encapsulated Materials—When the test specimen incorporates encapsulated materials, it is important to ensure that these materials have reached an equilibrium moisture content prior to assembly, and special arrangements shall be made with the applicant for the test to ensure that this is so.

13. Unexposed Face Temperature Thermocouples

13.1 Design—The temperature of the unexposed surface shall be measured by means of disk thermocouples of the type shown in Fig. 8. Thermocouple wires, 0.5-mm-thick noncombustible insulating pad. The pad material shall have a density of 900 ± 100 kg/m³.

13.2 Connection—Connection to the recording instrument shall be by wires of similar or appropriate compensating type.

13.3 Preparation of Surfaces to Receive Thermocouples:

13.3.1 Steel—Surface finishes shall be removed and the surface cleaned with a solvent. Loose rust and scale shall be removed by a wire brush.

13.3.2 Irregular Surfaces—A smooth surface not greater than 2500 mm², to provide adequate adhesive bond, shall be made for each thermocouple by smoothing the existing surface with a suitable abrasive paper. The material removed shall be the minimum to provide adequate bonding surface. Where the surface cannot be smoother, fillings shall be used of minimum quantity to provide a suitable surface. The filling shall comprise a ceramic cement, and when the filled surface is dry, it shall be smoothed, if necessary, with abrasive paper.

13.4 Fixing of Thermocouples:

13.4.1 Steel—The insulating pad with the thermocouple fitted shall be bonded to the cleaned surface of the steel using a water-based ceramic cement produced by integrating the components to form a high-temperature resistant adhesive. The adhesive shall be of such a consistency that no mechanical aid is necessary for retention purposes during the drying process, but where difficulty in bonding is experienced, it is feasible that

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**NOTE 1**—Section 'A—A' (see Fig. 5 and Fig. 7).

**NOTE 2**—Section 'B—B' (see Fig. 5 and Fig. 7).
retention by adhesive tape will be used provided that the tape is removed sufficiently long in advance of removal of the tape to ensure that the insulating pad is not damaged. If the thermocouple pad is damaged when the tape is removed, then the thermocouple should be replaced.

13.4.2 **Mineral Wool**—The thermocouples with insulating pads fitted should be arranged in such a way that if a surface wire mesh is present it may aid retention, and, in all cases, the bond to the fibrous surface should be made using a contact adhesive. The nature of the adhesive necessitates a drying time before mating surfaces are put together, thus, obviating the need for external pressure.

13.4.3 **Mineral Fiber Spray**—Thermocouples should not be fitted until the insulation has reached a stable moisture condition. In all cases, the bonding technique for steel should be used, and, where a surface wire mesh is present, the thermocouples should be affixed to the insulation in such a way that the wire mesh aids retention.

13.4.4 ** Vermiculite/Cement-Type Spray**—The technique specified for mineral fiber spray shall be employed.

13.4.5 **Boards of Fibrous or Mineral Aggregate Composition**—The bonding technique for steel shall be used.

13.4.5.1 In all cases of adhesive bonding, the adhesive shall be applied in a thin film sufficient to give an adequate bond, and there should be a sufficient lapse of time between the bonding of the thermocouples and the test for stable moisture conditions to be attained in the case of the ceramic adhesive and evaporation of the solvent in the case of the contact adhesive.

13.5 **Positioning of Thermocouples on the Specimen**:

13.5.1 **Bulkheads and Decks**—The surface temperatures on the unexposed face of the test specimen shall be measured by thermocouples located as shown in Figs. 9 and 10:

13.5.1.1 Five thermocouples, one at the center of the test specimen and one at the center of each of the four quarters, all positioned no closer than 100 mm away from the nearest part of any joints welds or pins to any stiffeners;
13.5.1.2 Two thermocouples, one placed over each of the central stiffeners and positioned for a bulkhead at 0.75 height of the specimen, and positioned for a deck at mid-length of the deck;

13.5.1.3 Two thermocouples, each placed over a vertical (longitudinal) joint, if any, in the insulation system and positioned for a bulkhead at 0.75 height of the specimen and positioned for a deck at mid-length of the deck;

13.5.1.4 When a construction has two differently orientated joint details, for example normal to each other, then two thermocouples additional to those already described in 13.5.1.3 shall be used, one on each of two intersections;

13.5.1.5 When a construction has two different types of joint detail, then two thermocouples shall be used for each type of joint;

13.5.1.6 Additional thermocouples, at the discretion of the testing laboratory, shall be fixed over special features or specific construction details if it is considered that temperatures higher than those measured by the thermocouples previously listed are possible; and

13.5.1.7 The thermocouples specified in 13.5.1.4-13.5.1.6 for measurements on bulkheads, for example, over different joint types or over joint intersections, shall, where possible, be positioned in the upper half of the specimen.

14. Measurements and Observations on the Test Specimen During Test

14.1 Temperature:

14.1.1 The ambient air temperature at the beginning of the test shall be within the range from 10 to 32°C (50 to 90°F).

14.1.2 All temperature measurements shall be recorded at intervals not exceeding 1 min.

14.1.3 When calculating temperature rise on the unexposed surface of the test specimen, this shall be done on an individual thermocouple-by-thermocouple basis. The average temperature rise of the unexposed surface shall be calculated as the average of the rises recorded by the individual thermocouple used to determine the average temperature.

14.1.4 For bulkheads and decks, the average temperature rise on the unexposed face of the specimen shall be calculated from the thermocouples specified in 13.5.1.1 only.

14.2 Deformation—The maximum deflection of specimen shall be recorded during the test. These deflections and displacements shall be measured with an accuracy of ±2 mm.
14.3 General Behavior—Observations shall be made of the general behavior of the specimen during the course of the test and notes concerning the phenomena such as cracking, melting or softening of the materials, spalling or charring, and so forth, of materials of construction of the test specimen shall be made. If quantities of smoke are emitted from the unexposed face, this shall be noted in the report. However, the test is not designed to indicate the possible extent of hazard due to these factors.

15. Performance Criteria

15.1 The average unexposed face temperature rise as determined by averaging the five thermocouples as described in 13.5.1.1 shall not be more than 140°C (250°F), and the temperature recorded by any of the individual unexposed face thermocouples shall not be more that 180°C (325°F), during the following periods for each classification:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class H-120</td>
<td>120</td>
</tr>
<tr>
<td>Class H-60</td>
<td>60</td>
</tr>
<tr>
<td>Class H-30</td>
<td>30</td>
</tr>
<tr>
<td>Class H-15</td>
<td>15</td>
</tr>
</tbody>
</table>

16. Report

16.1 Report all important information relevant to the test specimen and the fire test including the following specific items:

16.1.1 The name of the testing laboratory and the test date.
16.1.2 The name of the applicant for the test.
16.1.3 The name of the manufacturer of the test specimen and of the products and components used in the construction, together with identification marks and trade names.
16.1.4 The constructional details of the test specimen, including description and drawing and principal details of components. All the details of the specimen shall be give. The description and the drawings, which are included in the test report, shall, as far as practicable, be based on information derived from a survey of the test specimen.
16.1.5 All the properties of materials used that have a bearing on the fire performance of the test specimen together with measurements of thickness, density and, where applicable, the moisture or binder content, or both, of the insulation material(s) as determined by the test laboratory.
16.1.6 A statement that the test has been conducted in accordance with the requirements of these test methods (and if any deviations have been made to the prescribed procedures and a witness and their affiliation) and a clear statement of the deviations.
16.1.7 The name of the witness and their affiliation present at the test; when a test is not witnessed by a certifying authority, a note to this effect shall be made in the report.
16.1.8 Information concerning the location of all thermocouples fixed to the specimen, together with tabulated data obtained from each thermocouple during the test. Additionally a graphical depiction of the data obtained shall be included. A drawing shall be included which clearly illustrates the positions of the various thermocouples and identifies them relative to the temperature/time data.

16.1.9 The average and the maximum temperature rises, recorded at the end of the period of time appropriate to the insulation performance criteria for the relevant classification of insulation. If the test is terminated due to the insulation criteria having been exceeded, the times at which limiting temperatures were exceeded.

16.1.10 The individual unexposed thermocouple readings at each time interval. The average, as described in 14.1.2, and maximum thermocouple at each time interval.

16.1.11 The individual furnace thermocouple reading at each time interval. The average furnace thermocouple reading at each time interval.

16.1.12 Observations of significant behavior of the test specimen during the test and photographs or video recordings or both.

17. Precision and Bias

17.1 The precision and bias of these test methods have not yet been determined.

18. Keywords

18.1 bulkhead, deck; fire test response; hydrocarbon pool fire; restricted, unrestricted, insulation; temperature, heat flux
A1. TOTAL HEAT FLUX SENSOR ("CALORIMETER")

A1.1 General Description—For measurement of total heat flux, a water-cooled circular foil “Gardon Gage” heat flux sensor shall be used. A general description of this type of gage is given in Test Method E 511, which was developed by ASTM Subcommittee E21.08. While it is used to make total heat flux measurements, this device is designed for making radiative heat flux measurements. Caution must be exercised when using this gage to make measurements with a large convective fraction as a result of calibration constant changes. Additional information is contained in the literature (1-4). This rapid-response sensor derives its output from a differential thermocouple circuit that measures the temperature difference between the center and periphery of the active sensing area (which is the water-cooled circular foil). This millivolt area output is self-generating and is directly proportional to the total heat flux.

A1.2 Specifications:
A1.2.1 View Angle—180°.
A1.2.2 Accuracy—±3 % of reading (radiative fluxes only).
A1.2.3 Linearity—±2 % of full range.
A1.2.4 Repeatability—±1/2 %.
A1.2.5 Response Time—0.5 s or less.
A1.2.6 Surface Coating Absorptivity—To be specified by the manufacturer for a 2500°R (139K) blackbody radiation spectrum.

A1.3 Calibration:
A1.3.1 Each instrument shall have a certified calibration for the range of intended use, directly traceable to the National Institute for Standards and Technology (NIST). The instrument shall have a certified recalibration, for the range of intended use, directly traceable to the NIST range if intended use, directly traceable to the NIST whenever there is reason to suspect that recalibration is required (for example, if there is a change in the appearance of the sensor coating); or at least once per year, or after 25 testing hours, whichever comes first.
A1.3.2 Before each use, each instrument should have a recalibration performed by the testing laboratory that is either directly or indirectly traceable to NIST.

A1.4 Operation—Because condensation on the surface of the sensor can cause faulty readings, the temperature of the sensor shall be kept above 120°F (50°C) or above the dew point of the local environment, whichever is greater.

A1.5 Mounting and Use—Sensors shall be mounted in the calibration fixtures. The sensors shall be mounted where there is no direct flame or high-velocity jet impingement. The water-cooling must be capable of maintaining foil edge temperature less than 300°F (150°C).

A1.6 Acceptable Sensors—Several sensors have been verified by their manufacturers to meet the requirements of A1.1 through A1.2.

A1.7 Radiometers and Calibrations—Radiant heat flux measurements are not required in the test method. If radiant heat flux measurements are desired, radiometers based on the designs of the total heat flux sensors are available. If the radiometer uses a window, calibration of the sensors shall be performed with the window in place and use a thermal source with a radiation spectrum similar to that present in a furnace at 2500°R (139K).

APPENDIXES

X1. COMMENTARY

X1.1 Introduction—This commentary has been prepared to provide the user of these test methods with background information and rationale on the development of these test methods and the selected standard test condition. These test methods are primarily intended for evaluation of materials used for fire protection of structures in the hydrocarbon processing industry (HPI) (such as oil refineries, petrochemical plants, offshore oil-production platforms, and so forth), and other structures that can be exposed to large, free-burning, fluid hydrocarbon-fueled, pool fires. No attempt has been made to incorporate all the available information on pool fires in this commentary.

X1.2 Basic Differences in Large Pool Fire Test Versus Test Methods E 119—Before the development of these test methods, Test Methods E 119 were the only standardized tests available
for evaluation of the thermal response of structural members and assemblies to fires. These test methods differ from Test Methods E 119 in two major ways:

X1.2.1 When a furnace is used to produce the thermal exposure, the primary control for these test methods is based on a calibration procedure that develops a time-temperature curve to produce a specified heat flux incident upon the test specimen.

X1.2.2 These test methods get hotter faster than in Test Methods E 119, which consequently subjects the test specimens to a strong thermal shock. Specifically, these test methods specify a cold wall heat flux of 204 kW/m² (65 000 Btu/ft²-h) upon the test specimen within 5 min of test initiation. This compares to values measured in a major Test Methods E 119 furnace of 35 kW/m² (11 100 Btu/ft²-h) at 5 min and 18 kW/m² (37 400 Btu/ft²-h) at 60 min (5).

X1.2.3 Need to Control Heat Flux—The heat flux incident upon an object is defined as energy per unit area per unit time (for example, Btu/ft²-h (kW/m²)). During the initial stages of the fire, the thermal response of an object to the fire is a direct function of the heat flux to which the object is exposed (5-9). While temperature is an important driving force for heat flux, temperature alone does not sufficiently define a fire environment. For example, both a match and a large pool fire (for example, 50 ft in diameter) burn in a roughly similar temperature regime (from 871 to 1093°C (1600 to 2000°F)), but clearly a person can safely get within a few inches of a match. The reason is, that the size of the pool fire results in a much higher incident heat flux. Therefore, it is temperature as well as other factors, such as fire size, flame thickness, and so forth, that cause heat flux. One study of Test Methods E 119 concluded:

Exposure severity is given indirectly and incompletely by specification of the furnace temperature. The true measure of severity is given by the heat flux. Our overriding conclusion is to recommend that future improvements of Test Methods E 119 focus more on the control, measurement, and specification of the heat flux condition rather than the ambient gas temperature history (10).

Therefore, specifying a combination of the heat flux and the temperature for the control of these test methods represents an advance in fire technology, not a unique requirement for large pool fires as such.

X1.3 Need for a Large Hydrocarbon Pool Fire Test:

X1.3.1 A large pool fire is loosely defined as that resulting from hundreds (or thousands) of gallons of liquid hydrocarbon fuel burning over a large area (several hundred to several thousand square feet) with relatively unrestricted air flow to it and combustion products from it (for example, outdoors). A number of large pool fire experimentalists (11-18) have shown that high heat flux and temperature conditions are rapidly achieved in this fire (typically in less than 1 min.) This is in sharp contrast to the slow rate of buildup of thermal conditions in the Test Methods E 119 fire, which simulates a fire in which the fuel is solid and restrictions exist on air flow to (and combustion products from) the fire.

X1.3.2 The HPI facilities, which largely are located outdoors, handle large quantities of hydrocarbon fluids. Personnel responsible for safety and loss prevention in these facilities are concerned that when they have a fire of consequence, it is a large pool fire, not a Test Methods E 119 type fire, and that structures, assemblies, and fire protection materials should be designed based on ratings in a large pool fire, not the Test Methods E 119 fire (19-22). Indeed, Norway now specifies firewalls on offshore platforms rated per a hydrocarbon fire (23).

X1.3.3 The concern for materials and structural performance in large pool fires has led to the development of several different types of large pool fire simulation tests (5, 6, 20, 24-27) that have shown that materials can perform quite differently in Test Methods E 119 versus pool fire test. For example, one experimenter showed that 2 in. of a standard fireproofing material gave only 1 h in a pool fire simulation test versus a nominal 3-h Test Methods E 119 rating (20).

X1.3.4 However, the existence of various simulation tests has sometimes led to confusing and conflicting results, and the lack of a standardized test has inhibited acceptance of ratings in accordance with this test method (21). Therefore, the need was established for this standardized test method that simulates the effects of large pool fires on the types of structures and assemblies that are used in HPI facilities.

X1.4 Rationale for the Specific Test Conditions:

X1.4.1 Need for a Single Set of Test Conditions—To establish a standardized large pool fire simulation test, the issue becomes one of selection of the conditions to simulate. As demonstrated by the various large pool fire experimenters, a range of temperatures, velocities, heat fluxes, and chemical conditions exist, and they vary dramatically with time and spatial location (12, 14). From a pragmatic viewpoint, selection of multiple test conditions would probably result in prohibitively high testing costs. Therefore, it becomes a case of whether engineering judgment can be exercised in selecting a single set of test conditions that represent a reasonable worst case for HPI facility design purposes.

Note: X1.1—Reasonable worst case means, in essence, designing to withstand the most severe set of conditions that could be expected, within reason, to occur. Note that the design solution for a structure exposed to the reasonable worst case set of fire conditions selected does not necessarily have to be limited exclusively to passive fire protection, but can, and generally does, include a combination of passive plus active systems fixed and mobile.

X1.4.2 Radiant Heat Flux and the Continuous Total Flame Envolvement Criterion—There is a consensus that radiation is the dominant heat transfer mechanism to an object immersed in a large pool fire (6, 9, 11, 12, 14, 17). Radiant heat transfer to an object is defined by the Stefan-Boltzmann equation as follows:

\[
q = \sigma e FT^4
\]  

(X1.1)

where:

\( q \) = radiative heat flux incident on the exposed time, \( \text{kW/m}^2 \) (Btu/ft²-h);

\( \sigma \) = Stefan-Boltzmann constant, \( 5.67 \times 10^{-11} \text{kW/m}^2 \text{K}^4 \);
\[ \epsilon = \text{emissivity of the fire as viewed from the exposed item} \]
\[ F = \text{view factor of the exposed item to the fire (by definition} \]
\[ T = \text{absolute temperature of the fire, °R or K}. \]

Therefore, to determine a reasonable worst case radiation condition, consideration must be given to the view factor to the fire, fire emissivity, and time continuity, as well as fire temperature.

X1.4.2.1 View Factor—Only those surfaces of an object that are in a direct visual line to a fire can receive heat flux. Because an object located outside of, or on the periphery of, a fire has a view factor (to the fire) of 0.5 or less, it is clear that maximum radiation occurs when the object is fully engulfed in the fire and hence has a view factor of 1.0 (which is the theoretical maximum) and that this is a reasonable maximum.

X1.4.2.2 Emissivity of a Fire—By definition, emissivity ranges from zero (for example, no flames at all) to 1.0 (for example, flames so thick that they cannot be optically seen through). Experimenters are tending to believe that in a fire that has a large quantity of luminous soot particles (such as a liquid hydrocarbon fueled pool fire), flames only have to be 3 to 6 ft thick to be optically opaque (15). Clearly, then, it is a reasonable maximum to have an emissivity of 1.0.

X1.4.2.3 Time Continuity—This is perhaps the most important factor. Consider an example of fire exposure of an individual structural member, such as a beam or column, centered in a pool fire on the order of 30 to 40 ft in diameter. It is clear that, at least at some times during the fire, an optically opaque fire can totally engulf the beam or column. Hence it is reasonable for the view factor and fire emissivity to be 1.0 at some times, with respect to the beam or column. The question then must be answered: For what percentage of the time duration of the fire (for example, if it is a 1-h fire) do these conditions prevail? Since these pool fire predominantly occur outdoors, and since even small winds can cause the fires to fluctuate greatly in a given space (Note X1.2) (12, 15-18), this is a very difficult question to answer. Therefore, an assumption has to be made, and the reasonable worst case assumption made is that the total engulfment conditions prevail 100% of the duration of the fire exposure. In other words, total continuous engulfment means that at no time during the fire does any part of the structural member ever see out (nor would an imaginary observer anywhere outside of the fire ever see in to the member). Because the performance of any individual member (for example, a column) can be critical, this total continuous engulfment criterion designs the member as if it were in the central portion of a large stationary fuel spill on a relatively windless day for the duration of the protection time desired (for example, 1.0 h).

Note X1.2—Indeed, virtually all large pool fire experimenters specifically wait for windless (or special prevailing wind) conditions to conduct their fires so they have a measure of control on their experiment.

X1.4.3 Total Heat Flux:

X1.4.3.1 The specified total heat flux is 204 kW/m²·h (65 000 Btu/ft²·h²) within 5 min of fire initiation, and is a summation of the radiative plus convective components, with the radiative component being very dominant:

\[ q_r = q_c = q' \]

where:

\[ q_r = \text{total heat flux, kW/m}^2 \text{ or Btu/ft}^2\cdot\text{h}; \]
\[ q_c = \text{radiant heat flux, see Eq X1.1; and} \]
\[ q_c = \text{convective heat flux, } h(T_f - T_s) \text{ (see Eq X1.3)}. \]

Therefore, total heat flux is a strong function of fire temperature(s), and the convective component is a function of the temperature and velocity of the gases in the fire. In X1.4.4 and X1.4.5, fire temperature and gas velocity are discussed.

X1.4.3.2 Measurement of heat flux in a fire is a difficult experimental task. However, it is surprising how much agreement there is between experimenters, given this experimental difficulty plus the fluctuation of conditions within a given fire, as well as the differences in types and sizes of fires and where and how the heat flux measurements are made and other variables (for example, wind).

(1) Bader of Sandia (11) measured heat fluxes in large pool fires by several methods and developed a simplified computer model to predict the response of an object immersed in the fire. Using slug (that is, solid metal) calorimeters, the maximum time-integrated measured heat flux in 5.5- by 5.5-m (18- by 18-ft) fires was 150 kW/m² (47 500 Btu/ft²·h). For modeling of an object’s response, he states:

It was realized that both radiant and convective heat transfer played significant parts as energy transfer modes within a fire, but it was reasoned that at high temperature the radiant mode would be dominant, blackbody source temperature which would combine the effects of radiation and convection. A study of experimental temperature measurements was undertaken. After analyses, “It was decided that a good numerical representation of a large free-burning fire was possible using an 1850°F (1010°C) blackbody temperature as the input.”

Note X1.3—This input began at –1 min after fire initiation. Blackbody radiation at 1850°F (1010°C) gives a heat flux of 48 800 Btu/ft²·h (154 kW/m²).

(2) Canfield and Russell of the U.S. Navy (12) mapped the temperature and radiant heat flux (using Gardon gages) at up to 32 points in the flame plume of a 16- by 8-ft (4.9- by 2.4-m) pool fire. The maximum means value of radiant heat flux was 51 000 Btu/ft²·h (161 kW·m²), this being in the (spatially) small hot core of the flames (measured from 1945 to 1974°F (1063 to 1079°C).

(3) NASA and Avco (13) measured total heat flux in a 48- by 54-ft (14.6- by 16.5-m) pool fire using a Gardon gage. The maximum total heat flux measured was 50 600 Btu/ft²·h (160 kW/m²).

(4) Brown of the FAA (16) also used Gardon gages to measure total heat flux at one point in a series of 20- by 20-ft (6.1- by 6.1-m) pool fires under various wind conditions. The result: “The heat flux to the . . . calorimeters averaged about 50 400 Btu/ft²·h (159 kW/m²) for calm wind or steady perpendicular wind (blowing fire toward calorimeter) tests.” (The heat...
fluctuations was about 18,000 Btu/ft²·h (56.7 kW/m²) for wind blowing away. The heat flux reached quasisteady state values in less than 20 s.

(5) Mansfield of NASA (14) also used Gardon gages. The fires were 25 by 25 ft (7.6 by 7.6 m) and 30 by 80 ft (9.1 by 9.1 m). The average total heat flux of three points was 50,800 Btu/ft²·h.

(6) In a series of tests at Sandia National Laboratories (17, 18, 28), a variety of flat plate and cylindrical calorimeters have been used in 30- by 60-ft (9- by 18-m) pool fires to obtain hot wall heat fluxes to objects of different sizes and shapes. The maximum average value of the cold wall heat flux in these test methods was slightly less than 50000 Btu/ft²·h (158 kW/m²).

X1.4.3.3 Therefore, the selected value of 50,000 Btu/ft²·h (158 kW/m²) is a reasonable average of the experimental values. This is assumed to be a reasonable worst-case exposure.

X1.4.4 Convective Heat Flux and Gas Velocity:

X1.4.4.1 While the convective heat flux is not called out separately in these test methods, on a vertical column it is expected to be approximately 10% of the total heat flux or about 5000 Btu/ft²·h (16 kW/m²) (see X1.4.4.4).

X1.4.4.2 Convective heat flux to an object occurs as the result of the flow over the object of gases of higher temperature than the object. For an object of a given shape (for example, a 9-ft tall column), and gases of a given temperature and composition, the convective heat flux is a function of the velocity of the gases and their orientation to the object. In the continuous engulfment portion (see X1.4.2) of a large pool fire, the prevalent (time-wise at any one spatial point) velocity of the combustion gases is vertical as a result of the buoyant forces of the flame plume (for example, in comparison to any wind conditions that could exist which would add horizontal component to the gas velocity, and to very sporadic cyclone-type whirling vortices). For the example of a 9-ft (2.7-mm) tall column, the flow is parallel to the 9-ft height and is turbulent and the convective heat flux can be quantified as follows:

\[ q_c = h_{avg} (T_g - T_s) \]  
\[ h = 0.0037 \times (k/L) \times (V/Lv)^{0.8} \times Pr^{0.33} \]

where:

- \( q_c \) = cold wall convective heat flux, Btu/ft²·h; wall at 70°F;
- \( h_{avg} \) = average heat transfer coefficient, Btu/ft²·h · oF;
- \( T \) = average gas temperature, °F;
- \( L \) = height of the column, ft;
- \( k \) = thermal conductivity of the gases, Btu/ft²·h · °F;
- \( v \) = kinematic viscosity of the gases, ft²/h;
- \( Pr \) = Prandtl number; and
- \( V \) = average velocity of the gases, ft/h.

X1.4.4.3 Unfortunately, state-of-the-art heat transfer theory for buoyant plume velocities in large pool fires is corroboration. Theory (9, 29-33) states that maximum (vertical) velocity occurs at the centerline of a fire (under windless conditions), and increases with height (until a height is reached where lateral air entrainment/dilution effects cause the flame plume to become dissipated) (Note X1.3). Vertical velocity in general decreases with lateral distance from the fire centerline. Published data on velocity measurements is scarce. One published value of measured vertical plume velocity in a large pool fire is 38 ft/s (11.6 m/s) at a 20-ft (6.1-m) elevation at the exact centerline of a 50-ft (15.2-m) diameter fire (17). Reference (19) provides average velocities at the centerline of a 9 by 18 m, and 9.5 m/s at 6.1 m; velocities measured during periods of low winds are up to 30% higher. References (18, 29-33) provide theoretical analysis.

X1.4.4.4 Using Eq X1.3 and X1.4, and using \( T = 2000°F \) (1093°C) and estimated properties (that is \( k, v, Pr \)) for the combustion gases, \( q_c \) computes to slightly of 5000 Btu/ft² is total specified heat flux of 50,000 Btu/ft²·h (159 kW/m²). This agrees well with Mansfield’s observation (14). “This division of radiant and convective energy transfer is similar to a frequently accepted average or standard radiant/convective ratio of 9:1 for large pool fires.”

X1.4.4.5 Although theory predicts higher velocities at higher elevations, common HPI design practice limits the major areas of fire protection concern to a maximum of 30 to 40 ft (9.1 to 12.2 m) above the fire source (23). The 20-ft (6.1-m) height at which the 38-ft/s (11.6-m/s) value was reported (17) or the 41-ft/s (12.6-m/s) value reported in (18) during low winds are therefore at the approximate average height of HPI concern. Note that the data reported (18) show that the temperatures at this elevation are lower than at some elevations closer to the pool surface.

X1.4.4.6 As a counterpoint to the discussion of X1.4.4.4, the possibility exists that some fireproofing materials might be susceptible to erosive damage because of exposure to high-temperature gases with velocities representative of those measured in large pool fires. However, preliminary analysis of measurements made in large pool fires at Sandia National Laboratories, gives a shear stress estimate of less than 1 psf (50 Pa). As technology advances, this entire subject of gas velocity and its effects is one that could use further attention.

X1.4.4.7 As a pragmatic point, it is extremely difficult and expensive experimentally to generate high velocities of large quantities of hot gases and direct them in a highly controlled manner on a large test specimen. In fact, it is not clear if any existing test facility, other than an actual fire, has the capability of generating the representative velocities.

X1.4.5 Fire Temperature:

X1.4.5.1 The specified fire temperature (that is, the temperature of the environment that generates the heat fluxes of X1.4.3 and X1.4.4) is from 1850 to 2150°F (1010 to 1180°C). While this range is narrower than that seen in large pool fires (15, 17, 18), it was selected for two reasons:

(1) As the discussion in X1.4.5 presents, fires do not burn at any one temperature, but rather consist of gases with a wide range of temperatures, depending on spatial and time position in the fire. The range from 1700 to 2300°F (927 to 1260°C) is typical of the luminous plume engulfment region of large pool fires (12, 15, 17, 18). The selected range is in the middle of the broader range.

(2) The selected temperature range provides the experimenter/test facility with some flexibility and latitude in the means used to achieve the specified heat fluxes.

X1.4.5.2 As a reference point, using Eq X1.1 (the Stefan-Boltzmann equation for radiant energy transfer), if one is
disposed to think of the fire at a single idealized temperature, then for the blackbody radiation case of emissivity \(-1\) and view factor of \(F = 1\), \(T_f = 2000^\circ\text{F} (1093^\circ\text{C})\) gives an incident radiant heat flux of 63 770 Btu/ft\(^2\)-h (198 kW/m\(^2\)). Indeed, this concept of a single fire temperature is quite useful if an enclosed furnace is used as the test simulation facility. The heat flux of 65 000 Btu/ft\(^2\)-h called out in this test method would require a surface absorptivity of 0.8.

**X1.4.5.3** Temperature can be thought of as the driving potential for the heat flux. In actuality, the temperature in a luminous mass of combusting gases from a pool fire is not a constant but varies over a wide range, from about 1000 to 1200°F (538 to 649°C) at the air-entraining edge of the plume to a broad internal zone from 1200 to 1900°F (649 to 1038°C) to a small central hot core from about 1900 to 2200°F (1038 to 1204°C) (12, 15). One set of data for a spatially fixed grid of up to 50 thermocouples in the vertical cylindrical space over a 50-ft (15.2-m) diameter pool fire on a windless day gave the following time-averaged volumetric distribution (31):

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1200°F (649°C)</td>
<td>66 %</td>
</tr>
<tr>
<td>1200 to 1900°F (649 to 1038°C)</td>
<td>23 %</td>
</tr>
<tr>
<td>1900 to 2200°F (1038 to 1204°C)</td>
<td>11 %</td>
</tr>
</tbody>
</table>

Given the fluctuating nature of a pool fire, and therefore the probability that at some times the member will see out through the fire, thus counterbalancing exposures to higher temperatures, the specified range appears to meet the criterion of a reasonable worst case.

**X1.4.6 Gas Chemistry and Oxygen Content:**

**X1.4.6.1** While the chemistry of the gases adjacent to the test specimen are not specified in these test methods, some discussion of these topics was considered appropriate for commentary.

**X1.4.6.2** The chemistry in the fire plume of a pool fire is, like temperature, not a constant, but dynamic with time and spatial position. On the one hand, the chemistry is complex such as CO, CO\(_2\), HO, O, N, H, and C\(_n\)H\(_m\) (for example, various hydrocarbons), soot particles, and so forth. On the other hand, the chemistry is relatively straightforward—that of a fluid hydrocarbon reacting with air. Therefore, the range of chemical species present are relatively well known.

**X1.4.6.3** The most extensive measurement of chemistry in a pool fire is given by Ref (15), where up to 23 spatial points were sampled periodically in the cylindrical area over a 50-ft (15.2-m) diameter pool fire. One analysis of this data led to the statement: “The overall conclusion form the data presented is that in the JP-4 fuel fire there is very little oxygen at the center of the fire up to a height of 1.5 fire radius. That is, combustion is still taking place” (30). For the 50-ft diameter fire cited, a height of 1.5 fire radius is about 38 ft (11.6 m), approximately the normal maximum height of primary interest for fire protection (in accordance with the HPI; see X1.4.4.4).

### X2. USE OF FURNACE TYPE FACILITIES

**X2.1** While these test methods do not restrict the technique used to achieve the test conditions specified in Section 6 for the purposes stated in Section 1, there is strong interest in the use of traditional fire test facilities. The use of enclosed furnaces to simulate the thermal effects of a hydrocarbon fire is discussed.

**X2.2** Traditionally, enclosed furnace-type facilities have been used for testing of structural response of materials (for example, for Test Methods E 119 testing). These furnaces normally are fueled by a clean burning gas such as natural gas or propane. Experimental experience to date indicates that gas-fired enclosed furnaces are in concept also usable to simulate the pool fire conditions specified in Section 6 for the purposes specified in Section 1. The reason that an enclosed furnace type facility appears applicable to simulating the pool fire can be understood by referring to the discussion in X1.4.2, which explained that the 50 000-Btu/ft\(^2\)-h heat flux condition simulates total engulfment in the luminous portion of the flame plume. That is, the view factor \(F\) and emissivity are at the maximum value of 1.0. In addition, the fire is conceptualized as being at a uniform temperature of 1865°F (1018°C), as explained in X1.4.5.2. Consider a 2.7-m (9-ft) column in an enclosed furnace with optically opaque walls at 1865°F (1018°C) and with optically transparent gases in the furnace also at 1865°F (1018°C). The view factor of the column to the walls of the furnace is 1.0. If the walls of the furnace and the surface of the column are at a uniform temperature, the effective emissivity of the walls is 1.0 (Note Note X2.1). The radiant heat flux to the specimen in accordance with Eq X1.1 is the specified 65 000 Btu/ft\(^2\)-h. As long as the temperatures are uniform throughout the furnace, the same discussion for radiant heat fluxes holds true even if the gases in the furnace are not transparent.

**NOTE X2.1—**For the case of a fully enclosed furnace with optically opaque walls and at a uniform temperature, the radiosity (that is, the sum of the emitted and reflected radiation) of the walls is constant and equal to that of a blackbody at the same temperature, regardless of the materials of construction of the furnace (34). The walls have an effective emissivity of 1.0, regardless of the actual emissivity of the wall material. If the test specimen is at a temperature lower than that of the furnace walls, the heat flux to the specimen will drop below the blackbody flux based on the wall temperature. The size of the effect depends on the size of the test specimen relative to the furnace volume, the temperature difference, and the radiative properties of the test specimen and the furnace materials (35).
REFERENCES


(23) Norwegian Petroleum Directorate, Requirements for Offshore Platforms, Section 6, Passive Fire Protection.


Standard Specification for
Sound-Absorbing Board, Fibrous Glass, Perforated Fibrous Glass Cloth Faced

This standard is issued under the fixed designation F 2154; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers fibrous glass sound-absorbing board with a perforated fibrous glass cloth facing for sound reduction in ship spaces with high noise levels. This specification is primarily for materials used on ships. Additional requirements, testing, and certification are required for use of this material aboard U.S. Coast Guard inspected vessels in the United States.

1.2 This standard measures and describes the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of materials, products, or assemblies under actual fire conditions.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.

2. Referenced Documents
2.1 ASTM Standards:
   C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method\(^2\)
   C 634 Terminology Relating to Environmental Acoustics\(^2\)
   D 3951 Practice for Commercial Packaging\(^3\)
   E 84 Test Method for Surface Burning Characteristics of Building Materials\(^4\)

2.2 ANSI Standard:
   ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes\(^5\)

2.3 Other Documents:
   46 CFR 164.012 Code of Federal Regulations—Interior Finishes for Merchant Vessels\(^6\)
   Navigation and Vessel Inspection Circular (NVIC) 9-97\(^7\)

3. Terminology
3.1 For definitions of terms used in this specification, see Terminology C 634.

4. Ordering Information
4.1 Title, number, and date of this specification.
4.2 First article sample, when required (see 7.1).
4.3 Width and length required, if other than 24- by 36-in. (609.6- by 914.4-mm) board (see 8.1).
4.4 Thickness required (see 8.2).
4.5 Density of waffle board (see 10.1).
4.6 Conformance inspection reports required (see 11.1).

5. Materials and Manufacture
5.1 See typical construction details located in Supplementary Requirements Section S3.

6. Performance Requirements
6.1 Surface Flame Spread and Smoke Generation Properties—The sound-absorbing board shall meet the requirements for surface flame spread and smoke generation properties for an U.S. Coast Guard Approved Interior Finish in accordance with 46 CFR 164.012 or NVIC Circular 9-97.

6.2 Facing Separation—When the sound-absorbing board is cut or sawed, the threads of the fibrous glass cloth facing across which the cut is made shall not be separated from the face over a distance of more than 3.0 mm (¼ in.). In case the fibrous glass cloth facing does not cover the entire surface of the board, the uncovered portion of the board shall not extend further than 3.175 mm (¼ in.) from any edge. The fibrous glass cloth facing shall not extend over the edge of the board.

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\(^*\) This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.02 on Insulation/Processes.


\(^2\) Annual Book of ASTM Standards, Vol 04.06.

\(^3\) Annual Book of ASTM Standards, Vol 04.07.

\(^4\) Available from American National Standards Institute, 25W. 3rd St., 4th Floor, New York, NY 10036.


\(^6\) Available from Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250–7954.
6.3 Sound-Absorption—When tested as specified in 10.3, the sound-absorbing board shall have coefficients of absorption that are equal to or greater than those shown in Table 1.

7. Other Requirements

7.1 First Article—When specified (see Section 4), the contractor shall furnish sample unit(s) for first article inspection and approval (see 11.1).

8. Dimensions and Tolerances

8.1 Width and Length—Unless otherwise specified (see Section 4), the sound-absorbing board shall be furnished in a width of 609.6 mm (24 in.) and a length of 914.4 mm (36 in.) (see 11.2).

8.2 Thickness—The sound-absorbing board shall be furnished in thicknesses of 25.4 mm (1 in.) or 50.8 mm (2 in.), as specified (see Section 4 and 11.2).

8.3 Tolerances—Tolerances on length and width shall not exceed ±6.35 mm (¼ in.). Tolerance on thickness shall not exceed ±2.38 mm (⅜ in.) –0 mm (0 in.).

9. Sampling

9.1 Inspection Lot—For the purpose of sampling, a lot shall consist of all boards of the same thickness produced under essentially the same conditions, and offered for delivery at one time.

9.2 Sampling for Visual and Dimensional Examination—A random sample of board shall be selected from each lot offered for inspection in accordance with ANSI Z1.4 at Inspection Level II. No defects shall be allowed.

9.3 Conformance Test Sampling—When density and surface flame spread and smoke generation property tests are required in accordance with 11.1.2, the samples shall be selected in accordance with 9.3.1 and 9.3.2.

9.3.1 Sampling for Density Test—Sample boards shall be selected in accordance with ANSI Z1.4 at Inspection Level S-4 for the density test of 10.1. No defects shall be allowed.

9.3.2 Sampling for Surface Flame Spread and Smoke Generation Properties—A sufficient number of boards shall be randomly selected and joined end-to-end to form a specimen 50.8 cm (20 in.) wide by 50.8 mm (2 in.) thick by 731.5 cm (24 ft) long. The specimen shall be subject to the surface flame spread and smoke generation property test of 10.2.

10. Test Methods

10.1 Density—The density of the waffle board fibrous glass layer (see S3.1.2) shall be tested at the location of manufacture prior to fabrication into final form panels. Density is determined by dividing sample mass by sample volume. Sample mass is measured to the nearest 1.0 g and sample volume is measured to the nearest 1 cm³ of water displaced by one standard board as specified (see 9.3.1).

10.2 Surface Flame Spread and Smoke Generation Properties—The test specimens (see 9.3.2) shall be tested in accordance with Test Method E 84 (see S5).

10.3 Sound Absorption Coefficients—The sound-absorbing board shall be laid directly on the floor of a reverberation room and tested in accordance with Test Method C 423.

11. Inspection

11.1 Type approvals for 46 CFR 164.012 include inspection requirements as part of the specific type approval.

12. Packaging

12.1 Commercial Packaging—Commercial packaging shall be in accordance with Practice D 3951.

13. Keywords

13.1 fibrous glass cloth; perforated fibrous glass cloth; reverberation room method; sound absorbing; sound absorption coefficient; sound reduction; surface flame spread and smoke generation properties; waffle board

SUPPLEMENTARY REQUIREMENTS

(Mandatory Information for U.S. Navy)

This specification is adapted from MIL-A-23054.

S1. Supplemental Requirements and Exceptions to the Requirements of This Specification for Ships of the U.S. Navy

S1.1 DoD Intended Use—The sound-absorbing board covered by this specification is intended for reduction of sound in spaces where there is a high level of noise.
S2. Referenced Documents

S2.1 Military Specifications:
- MIL-I-742 Insulation Board, Thermal, Fibrous Glass
- MIL-A-3316 Adhesives, Fire-Resistant, Thermal Insulation
- MIL-C-20079 Cloth, Glass; Tape, Textile, Glass; and Thread, Glass

S3. Materials and Manufacture

S3.1 Material—The sound-absorbing board shall be a laminate consisting of a perforated fibrous glass cloth facing, a high-density fibrous glass layer waffle board, and a fibrous glass backing board. Asbestos fibers and components containing asbestos fibers are prohibited.

S3.1.1 Backing Board—The backing board shall conform to Type II of MIL-I-742 unfaced board except that the board shall be furnished in nominal thickness of 19.05 mm (3/4 in.) or 44.45 mm (1 3/4 in.) (see 5.1.2 and 8.2).

S3.1.2 High-Density Fibrous Glass Layer—The fibrous glass layer shall have a density of not less than 160 kg/m³ (10 lb/ft³) (see 10.1). The layer shall consist of glass fibers impregnated with a suitable binder and compressed or otherwise formed into a waffle. The nominal thickness of the high-density fibrous glass layer shall be 6.35 mm (1/4 in.).

S3.1.2.1 Waffle—The waffle shall be constructed having 4.76–mm (3/16-in.) deep indentations tapering from a nominal 6.0–mm (1/4-in.) diameter to a nominal 3.175–mm (5/32-in.) diameter indentations on a 12.7–mm (1/2-in.) center.

S3.1.3 Fibrous Glass Cloth Facing—The cloth used for facing the high-density fibrous glass layer shall conform to Type I, Class 2 of MIL-C-20079. The cloth facing shall be impregnated with a hardening agent. The cloth facing shall be perforated with nominal 4.76–mm (3/16-in.) diameter holes on a 12.7-mm (1/2-in.) center.

S3.1.3.1 Facing Adhesive—The impregnated fibrous glass cloth facing shall be compatible with adhesive conforming to Type II of MIL-A-3316. The adhesive strength requirements for securing fibrous glass cloth facing to the high-density fibrous glass layer shall conform to MIL-A-3316.

S3.2 Recycled, Recovered, or Environmentally Preferable Materials—Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

S3.3 Construction—One side of the high-density fibrous glass layer shall be adhered to the backing board and the other side adhered to the fibrous glass cloth facing, using adhesive. The fibrous glass cloth facing shall be free of wrinkles or other irregularities. The sound-absorbing board shall be so designed that the perforations in the fibrous glass cloth facing shall be centered over the indentations in the waffle-type high-density fibrous glass layer.

S4. Department of Defense Packaging

S4.1 DoD Packaging—For acquisition purposes, the packaging requirements shall be as specified in the contract or order. When actual packaging of material is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. Packaging requirements are maintained by the Inventory Control Point’s packaging activity within the Military Department or Defense Agency, or within the Military Department’s System Command. Packaging data retrieval is available from the managing Military Department’s or Defense Agency’s automated packaging files, CD-ROM products, or by contacting the responsible contracting activity.

S5. Performance Requirements

S5.1 Surface Flame Spread and Smoke Generation Properties—The sound-absorbing board shall have a flame spread index less than 30 and smoke development less than 100 when tested as specified in 10.2.

S6. Inspection

S6.1 Classification of Inspections—The inspection requirements specified herein are classified as follows: (1) first article inspection (see 11.1.1), and (2) conformance inspection (see 11.1.2).

S6.1.1 First Article Inspection—The first article inspection shall consist of the examination and tests shown in Table S6.1.

S6.1.2 Conformance Inspection—Conformance inspection shall consist of the visual and dimensional examination of S6.2. The density test of 10.1 shall be tested on each lot of material. New tests for density (10.1) and fire resistance (10.2) are required whenever the manufacturing methods or component materials are changed and reports supplied when requested.

S6.1.3 Examination—Each of the boards selected in accordance with 9.2 shall be examined to verify compliance with the dimensional requirements of this specification. When measuring length, width, or thickness, any convenient measuring rule graduated to 1.59 mm (1/16-in.) shall be used. Any board in the sample containing one or more defects shall be rejected. If the sample contains 3% or more of defective boards, the entire lot represented by the sample shall be rejected. The facing separation and workmanship examinations shall be included.

S6.1.4 Workmanship—The insulation shall be free of visual defects that will adversely affect the service quality. For example, holes or delamination of the facing when occurring to an excessive degree shall be judged to adversely affect the service quality of the material.

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**TABLE S6.1 First Article Inspection**

<table>
<thead>
<tr>
<th>Inspection Requirement Paragraph</th>
<th>Examination and Test Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual and dimensional examination</td>
<td>8.1-8.3</td>
</tr>
<tr>
<td>Density</td>
<td>S3.1.2</td>
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<tr>
<td>Surface flame spread and smoke generation properties</td>
<td>10.2</td>
</tr>
<tr>
<td>Sound absorption</td>
<td>6.3</td>
</tr>
</tbody>
</table>
Standard Specification for
Packing Material, Graphitic, Corrugated Ribbon or Textured
Tape, and Die-Formed Ring

This standard is issued under the fixed designation F 2168; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Scope—This specification covers various types, classes,
and grades of flexible graphite material in which valve media
temperatures are limited to a maximum of 1050°F (966°C).
Where this specification is invoked as ASTM F 2168, Sections
1-18 apply. Where this specification is invoked as ASTM/DoD
F 2168, Sections 1-18 and the Supplementary Requirements
are applicable.

1.2 The values stated in SI units are to be regarded as
standard.

2. Referenced Documents

2.1 ASTM Standards:
- C 559 Test Method for Bulk Density by Physical Measure-
ments of Manufactured Carbon and Graphite Articles
- C 561 Test Method for Ash in a Graphite Sample
- C 816 Test Method for Sulfur in Graphite by Combustion-
Iodometric Titration Method
- C 889 Test Methods for Chemical and Mass Spectrographic
Analysis of Nuclear-Grade Gadolinium Oxide (Gd₂O₃)
Powder
- D 129 Test Method for Sulfur in Petroleum Products (Gen-
eral Bomb Method)
- D 512 Test Methods for Chloride Ion in Water
- D 1179 Test Methods for Fluoride Ion in Water
- D 1246 Test Method for Bromide Ion in Water
- D 3178 Test Methods for Carbon and Hydrogen in the
Analysis Sample of Coal and Coke
- D 3684 Test Method for Total Mercury in Coal by the
Oxygen Bomb Combustion/Atomic Absorption Method
- D 3761 Test Method for Total Fluorine in Coal by the
Oxygen Bomb Combustion/Ion Selective Electrode
Method
- D 3951 Practice for Commercial Packaging
- D 4239 Test Methods for Sulfur in the Analysis Sample of
Coal and Coke Using High Temperature Tube Furnace
Combustion Methods

3. Terminology

3.1 Definitions:
- accordion crease, n—because of the method of con-
struction of die-formed rings, an accordion-like linear indica-
tion (crease) may appear singularly or in multiple locations
around the inside and outside diameter surface.
- corrosion inhibitors, n—additives to the products to
function in a passive or sacrificial manner to reduce galvanic
corrosion. These additives are typically embedded zinc pow-
der, phosphorus, or barium molybdate.
- corrugated ribbon, n—graphite ribbon or tape that is
subjected to mechanical pressure in a consistent manner to
apply surface indentations to the tape or ribbon.
- density, n—the mass per unit volume at a specified
temperature.
- detrimental materials, n—abrasive or chemically ac-
tive constituents such as ash particles (in high ash content foils)
or elemental materials that can cause galvanic action or
corrosion in long-term storage or service environments.
- die-formed ring, n—a packing ring made by mechani-
cally compacting winds of graphite ribbon or braided packing
in a die or fixture.
- lot, n—all finished packing of one size, type, class,
and grade produced in a continuous run or at the same time
under essentially the same conditions.
- set, n—the packing components required to pack one
valve.
- size, n—refers to the physical dimensions of the
packing material.

4. Classification

4.1 Classification—The material shall be of the following
types, classes, and grades as specified (see Section 5).

4.1.1 Type I—Corrugated ribbon or textured tape.

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1 This specification is under the jurisdiction of ASTM Committee F25 on Ships
and Marine Technology and is the direct responsibility of Subcommittee F25.02 on
Insulation Systems.
3 Annual Book of ASTM Standards, Vol 15.01.
5 Annual Book of ASTM Standards, Vol 10.03.
7 Annual Book of ASTM Standards, Vol 05.06.
4.1.2 Type II—Die-formed ring.
4.1.3 Class I—For use where detrimental material content of the packing need not be controlled beyond normal manufacturing limit (commercial grade).
4.1.4 Class 2—For use where detrimental material content must be controlled to the limits specified herein.
4.1.5 Grade A—Treated with corrosion inhibitor.
4.1.6 Grade B—No corrosion inhibitor.

5. Ordering Information
5.1 Contracts or orders for the units under this specification shall include the following information:
5.1.1 Title, number, and date of this specification.
5.1.2 Type, class, and grade.
5.1.3 Type of corrosion inhibitor (see 6.1.3 and Supplementary Requirements).
5.1.4 Specify density of die-formed rings.
5.1.5 Inspection, testing, and certification of the material should be agreed upon between the purchaser and the supplier as part of the purchase contract (see Sections 14 and 16).
5.1.6 When die-formed (Type II) packing rings are desired, the ring height, inside diameter, outside diameter, number of cuts, and number of packing rings required per set (see 9.2 and 9.3).
5.1.7 Marking requirements (see Section 17 and Supplementary Requirements).
5.1.8 Packaging requirements (see Section 18 and Supplementary Requirements).
5.1.9 Application data (to include operating pressure, operating temperature, and media).
5.1.10 Specify thickness of Type I.

6. Materials and Manufacture
6.1 Material—Requirements specified herein apply to Class 1 and Class 2 and Grade A and Grade B packing, except where noted.
6.1.1 Type I—The packing shall be made entirely of flexible graphitic material having no binders and meeting the requirements of Tables 1 and 2.
6.1.2 Type II—Die-formed packing rings shall be manufactured from flexible graphitic material conforming to the requirements of Tables 1 and 2.
6.1.3 Coating and Corrosion-Inhibiting Treatments:
6.1.3.1 Grade A—Grade A packing shall be provided with a powdered zinc active corrosion-inhibiting treatment or a passive inhibiting treatment such as phosphorous or barium molybdate, as specified (see Section 5). If the use of inhibitors is required, both passive and active inhibitors shall be permitted to be used.
6.1.3.2 Grade B—Grade B packing shall not contain corrosion-inhibiting additives.

6.1.4 Mercury Exclusion—During manufacturing, fabrication, handling, packaging, and packing, the packing material shall not come in contact with mercury or mercury containing compounds.

7. Properties
7.1 Chemical and Physical Properties—Unless otherwise specified, the properties of the finished packing shall conform to the requirements of Table 1. Class 2 also requires compliance with Table 2.
7.2 Prohibited Additions—There shall be no intentional additions of any of the detrimental materials of Table 2 or antimony (Sb), arsenic (As), bismuth (Bi), cadmium (Cd), gallium (Ga), indium (In), lead (Pb), mercury (Hg), silver (Ag), or tin (Sn) during the manufacturing, fabrication, handling, packaging, and packing of the product.

8. Other Requirements
8.1 No other requirements noted.

9.1 Type I Ribbon Packing—Unless otherwise specified (see Section 5), the packing shall be uniformly coiled, spooled, or reeled in accordance with Table 3.
9.2 Type II Die-Formed Packing—Unless otherwise specified (see Section 5), the tolerances for Type II packing shall be in accordance with Table 4. The tolerance applies to finished rings before any cutting operations.
9.3 Split Rings—The number of cuts (zero, one, or two) shall be as specified (see Section 5). Cuts shall be made at approximately a 45° angle such that an overlapping joint is formed in the compressed state. When two cuts are required (separating the ring into two parts), the resulting parts shall be approximately the same dimension. If the number of cuts is not specified, single-cut rings shall be provided.

10. Workmanship, Finish and Appearance
10.1 Workmanship—The packing shall be free from extraneous material and visual defects that may affect its serviceability, as defined in Table 5.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, bulk</td>
<td>as specified</td>
<td>kg/m³</td>
<td>13.5</td>
</tr>
<tr>
<td>Ash</td>
<td>1 % by mass, max</td>
<td></td>
<td>13.3</td>
</tr>
<tr>
<td>Graphite purity</td>
<td>99 %, min</td>
<td></td>
<td>13.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Maximum Total Allowable Impurity Levels in Parts per Million (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury (Hg)</td>
<td>10</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>750</td>
</tr>
<tr>
<td>Total halogens (chlorine, bromine, and fluorine)</td>
<td>500</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>250</td>
</tr>
<tr>
<td>Bromine (Br)</td>
<td>250</td>
</tr>
<tr>
<td>Fluorine (F)</td>
<td>250</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 2 Detrimental Materials (Class 2 Only (See 13.6))</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TABLE 3 Dimensions for Type I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
</tr>
<tr>
<td>0.25 ± 0.030 in (6 ± 0.075 mm)</td>
</tr>
<tr>
<td>0.50 ± 0.030 in (12 ± 0.075 mm)</td>
</tr>
<tr>
<td>0.75 ± 0.030 in (18 ± 0.075 mm)</td>
</tr>
<tr>
<td>1.00 ± 0.030 in (25 ± 0.075 mm)</td>
</tr>
</tbody>
</table>
13. Test Methods

13.1 Tests—In the event tests are required as part of the purchasing requirements (see 5.1.5), tests shall be made in accordance with the following tests or by way of alternate methods of analysis with equal to or improved accuracy and precision. The use of an alternate analytical method requires prior written consent of the purchasing party before acceptance will be allowed. Except for the corrosion-inhibiting treatment exceptions of 13.3 and 13.4, all testing shall be performed on final product after completion of all processing, including application of any binders and, if required, corrosion inhibitors.

13.2 Size—The size shall be determined by measuring each sample selected for visual examination (see Table 4).

13.3 Ash Content—The ash content shall be determined in accordance with Test Method C 561 (see Table 1). For Grade A packing only, the test shall be conducted before the corrosion-inhibiting treatment or the added mass of the corrosion inhibitor shall be determined and subtracted from the base mass of the sample.

13.4 Graphite Purity—The sample shall be dried to a constant mass at 300 ± 5°F (149 ± 3°C) before testing. For Grade A packing only, the test shall be conducted before the corrosion-inhibiting treatment or the added mass of the corrosion inhibitor shall be determined and subtracted from the base mass of the sample. The percent carbon shall be based upon mass of the dried sample. This determination shall be made in accordance with Test Methods D 3178 or an alternate method of analysis with equal or improved accuracy and precision (see Table 1).

13.5 Bulk Density—The bulk density of the Type I and Type II materials shall be determined in accordance with Test Method C 559.

13.6 Detrimental Material Tests—For determination of the detrimental materials listed in Table 2 for Class 2 only, the test methods of Table 6 or alternate methods of equal or improved accuracy and precision shall be used.


14.1 Inspection and testing of the material should be agreed upon between the purchaser and the supplier as part of the purchase contract (see 5.1.5).

15. Rejection

15.1 Materials that fail to conform to the requirements of this specification shall be rejected. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of testing, the producer shall make claim for a rehearing or provide for third party testing.

<table>
<thead>
<tr>
<th>TABLE 4 Tolerances for Type II Packing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Diameter (i.d.)</td>
</tr>
<tr>
<td>to 1 in. (25 mm) o.d.</td>
</tr>
<tr>
<td>1 in. (25 mm) and above o.d.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 5 Classification of Visual Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>Type I corrugated ribbon or textured tape</td>
</tr>
<tr>
<td>Rip or tear in ribbon.</td>
</tr>
<tr>
<td>Particulate or extraneous matter on surface that is not easily removed without damaging the packing.</td>
</tr>
<tr>
<td>Noncontinuous length (no joints).</td>
</tr>
<tr>
<td>Lack of corrugation or textured surface area.</td>
</tr>
<tr>
<td>Creasing or crimping.</td>
</tr>
<tr>
<td>Type II die-formed rings</td>
</tr>
<tr>
<td>Delaminations (laminated rings).</td>
</tr>
<tr>
<td>Gouges (minor indentations less than 0.005 in. in depth resulting from normal production and handling are acceptable).</td>
</tr>
<tr>
<td>Split rings not cut cleanly.</td>
</tr>
<tr>
<td>Lack of corrosion inhibitor (Grade A only).</td>
</tr>
<tr>
<td>Wrong corrosion inhibitor (Grade B only).</td>
</tr>
<tr>
<td>Presence of corrosion inhibitor (Grade B only).</td>
</tr>
<tr>
<td>Cracking (crevices of no appreciable width associated with folds (accordion creases), ply terminations, or plies of die molded ribbon packing rings are acceptable.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 6 Detrimental Materials Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
</tr>
<tr>
<td>Chlorine (Cl), bromine (Br)</td>
</tr>
<tr>
<td>(2) D 129/D 512</td>
</tr>
<tr>
<td>(3) D 1246 (for bromine)</td>
</tr>
<tr>
<td>Fluorine (F)</td>
</tr>
<tr>
<td>(2) D 129/D 1179</td>
</tr>
<tr>
<td>(3) D 3761 (sample preparation and analysis)</td>
</tr>
<tr>
<td>Sulfur (S)</td>
</tr>
<tr>
<td>(2) C 816 (sample preparation and analysis)</td>
</tr>
<tr>
<td>(3) D 4239 Method 3 (sample preparation and analysis)</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
</tr>
<tr>
<td>(2) direct analysis of volatile elements by atomic absorption per D 3684</td>
</tr>
</tbody>
</table>
16. Certification

16.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been tested and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

16.2 Detrimental Materials Control—For Class 2 material only, the vendor shall provide certification that the limits of Table 2 have been met and that low melting metals (Sh, As, Bi, Cd, Pb, Sn, Ga, In, Ag, Hg and Zn [Zn for Grade B only]) have not been added as intentional constituents. In lieu of specific test results for the lot to be delivered, certifications shall be based on tests of both raw materials and production lots of similar finished packing material over an extended time period (not exceeding three years between tests). Any change to manufacturing processing that affects product composition, including changes to raw material, binders, or inhibitors (Grade A) shall require additional testing to form the basis for future certifications.

17. Product Marking

17.1 Marking—For commercial shipment, marking shall be in accordance with accepted industry practices or as required in the purchase contract (see 5.1.1). Marking shall include type of corrosion inhibitor, if any.

18. Packaging

18.1 Commercial Packaging—Commercial packaging shall be in accordance with Practice D 3951 or as required in the purchase contract (see 5.1.1).

19. Keywords

19.1 flexible graphite material; packing material

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. All of these supplementary requirements, and Sections 1-18, are applicable where this specification is invoked as ASTM/DoD F 2168. This specification is adapted from MIL-P-24503.

S1. Scope

S1.1 DoD Intended Use—Packing is intended for general shipboard service in valves with the exception of potable water. Grade A packing is intended for use in valves with noncorrosion-resistant (for example, carbon steel, 400 series stainless steel) stem and packing gland parts.

S1.1.1 Type I—Type I packing is in corrugated ribbon or textured tape form for use where packing gland dimensions are not uniform or known. Type I packing may be used to manufacture Type II packing locally.

S1.1.2 Type II—Because Type II packing is die formed, it is designed for applications in new equipment or equipment in which packing gland dimensions are uniform or known and in excellent mechanical condition. The die-molded ribbon packing requires only a drop-in, but not loose, clearance with final gland compression setting the rings for proper operation.

S1.1.3 Class 1—Class 1 is intended for use where detrimental materials content of the packing need not be controlled beyond normal manufacturing limits.

S1.1.4 Class 2—Class 2 is intended for use where detrimental materials content must be kept to a minimum.

S2. Classification

S2.1 The type and class classifications of this specification correspond to the type and class classifications of MIL-P-24503.

S2.2 The Grade B classification of this specification corresponds to the Grade N classification of MIL-P-24503.

S2.3 The Grade A classification of this specification, using zinc powder corrosion inhibitor only, corresponds to the Grade I classification of MIL-P-24503.

S3. Materials and Manufacture

S3.1 Density Requirements:

S3.1.1 Type I—Unless otherwise specified (see Section 5), density of corrugated ribbon/textured tape shall be 65 ± 10 lb/ft³ (1040 ± 160 kg/m³).

S3.1.2 Type II—Unless otherwise specified (see Section 5), density of finished die-formed rings shall be 90 ± 10 lb/ft³ (1440 ± 80 kg/m³).

S3.2 Coating and Corrosion-Inhibiting Treatments:

S3.2.1 Grade A—Grade A packing shall be provided with a powdered zinc active corrosion-inhibiting treatment (2% Zn by weight, minimum) only.

S3.2.2 Grade B—Grade B packing shall not contain corrosion-inhibiting additives.

S4. Dimensions and Tolerances

S4.1 Type I—Unless otherwise specified, (see Section 5), thickness of Type I packing shall be nominal 0.015 in. (0.38 mm).
S5. Quality Assurance

S5.1 As a minimum, manufacturers shall provide and maintain an inspection system that meets the requirements of ANSI/ASQC Q9003\(^9\).

S6. Test Methods

S6.1 Examination for Visual and Dimensional Defects—Each unit selected for visual and dimensional examination shall be surface examined and measured to determine conformance with the requirements that do not require tests (see Section 10, including Table 5, and 13.2, including Table 6).

S6.2 Examination for Preparation for Delivery—Each unit selected shall be visually examined to determine compliance with packaging requirements (see Section 5 and 9.1) and marking requirements (see Section 5 and 9.9).

S6.3 Simulated Performance—The test shall be conducted in an apparatus designed to simulate conditions in valves in actual service. A schematic of the test rig is shown in Fig. S6.1. The valves used in the simulator shall have glands and stems that are in as new condition. The entire piping system and valves shall be insulated so as to minimize heat loss. Thermocouples shall be installed so as to indicate the actual steam temperature. The simulator shall be capable of holding a temperature of 975 ± 25°F (524 ± 14°C) and a pressure of 1200 ± 50 lb/in.\(^2\) (84 ± 3.5 kg/cm\(^2\)) for the duration of the test. The packing shall be installed and the gland initially adjusted so that no leakage occurs with the system at its operating temperature and pressure. While pressurized, the valve shall be fully cycled manually not less than once every half hour (full close to full open). The following schedule shall be followed for running the test (test need not be conducted over a weekend period, if desired):

- 12 days ± 1 day at temperature 975 ± 25°F (524 ± 14°C) and 1200 ± 50 lb/in.\(^2\) (84 ± 3.5 kg/cm\(^2\)) pressure
- 35 days ± 5 days at ambient temperature and pressure (system shut down; valves need not be cycled)
- 5 days ± 1 day at temperature 975 ± 25°F (524 ± 14°C) and 1200 ± 50 lb/in.\(^2\) (84 ± 3.5 kg/cm\(^2\)) pressure

There shall be no steam leakage from the packing gland during the simulated performance test at a temperature 975 ± 25°F (524 ± 14°C) and 1200 ± 50 lb/in.\(^2\) (84 ± 3.5 kg/cm\(^2\)) pressure. There shall also be no corrosion or degradation of the packing gland at the completion of the test. Any leakage or gland adjustment shall be recorded. This test is equivalent to the simulated performance test of MIL-P-24503.

S7. Inspection and Testing

S7.1 Unless otherwise specified (see Section 5), first-article testing and quality conformance testing are required. The inspections and tests making up the first-article and quality conformance testing are as follows:

S7.2 Sampling for First-Article Testing—A sample shall be subjected to the first-article testing of Table S7.1.

S7.3 Sampling for Quality Conformance Testing:

S7.3.1 Sampling for Visual and Dimensional Examination—As a minimum, the contractor shall randomly select a quantity of sampling units from each lot in accordance with Table S7.2 and subject them to the examination for visual and dimensional defects of S6.1. The sample size depends on the lot size. If one or more defects are found in any sample, the entire lot shall be rejected. The contractor has the option of screening 100% of the rejected lot for the defected characteristics or providing a new lot, which shall be inspected in accordance with the sampling plan herein. The contractor shall maintain for a period of three years after contract completion, records of inspections, tests, and any resulting rejections.

S7.3.2 Sampling for Chemical and Physical Property and Detrimental Materials Tests—A single random sample shall be selected from each lot for the testing of 13.3-13.6.

S7.3.3 Sampling for Examination for Preparation for Delivery—The lot size is the number of shipping containers. Sampling shall be in accordance with Table S7.2.

S8. Certification

S8.1 Simulated Performance Test—After the simulated performance test is once performed acceptably, providing product composition or processing has not changed, a certificate of compliance, citing the test report or document accepting compliance with the test requirement, may be provided thereafter.

S9. Product Marking

S9.1 Item description marking shall include, as a minimum, the size, class, grade, and type of inhibitor (if any) of the graphitic packing material. In addition, the item description marking shall include the phrase “ASTM/DoD F 2168” to identify the applicability of this specification and any special marking which shall be required, such as bar coding (see Section 5).

<table>
<thead>
<tr>
<th>TABLE S7.1 First–Article and Quality Conformance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Article</td>
</tr>
<tr>
<td>Examination for visual and dimensional defects (S6.1)</td>
</tr>
<tr>
<td>Ash content (13.3)</td>
</tr>
<tr>
<td>Graphite purity (13.4)</td>
</tr>
<tr>
<td>Bulk density (13.5)</td>
</tr>
<tr>
<td>Detrimental materials (13.6)</td>
</tr>
<tr>
<td>(Class 2 only)</td>
</tr>
<tr>
<td>Simulated performance (S6.3)</td>
</tr>
<tr>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE S7.2 Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot Size</td>
</tr>
<tr>
<td>2 to 50</td>
</tr>
<tr>
<td>51 to 90</td>
</tr>
<tr>
<td>91 to 150</td>
</tr>
<tr>
<td>151 to 280</td>
</tr>
<tr>
<td>281 to 500</td>
</tr>
<tr>
<td>501 to 1200</td>
</tr>
<tr>
<td>1201 to 3200</td>
</tr>
<tr>
<td>3201 to 10 000</td>
</tr>
<tr>
<td>10 001 to 35 000</td>
</tr>
<tr>
<td>35 001 to 500 000 (and above)</td>
</tr>
</tbody>
</table>

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\(^9\) Available from the American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.
S10. Rejection

S10.1 Known Defects—Materials that fail to conform to the requirements of this specification shall not be offered for delivery.

S10.2 Buyer Testing—The buyer reserves the right to perform any of the inspections and tests set forth in this document. Materials that fail to conform to the requirements of this specification shall be rejected. Rejection will be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of testing, the producer may make claim for a rehearing or provide for third party testing.

S10.3 Replacement of Test Specimens—A test specimen shall be discarded and a replacement specimen selected from the same lot of material under the following conditions:

S10.3.1 Where the specimen is incorrectly prepared,
S10.3.2 Where the test procedure is incorrect,
S10.3.3 Where there is a malfunction of the testing equipment, and
S10.3.4 Where a flaw that is not indicative of an inferior or defective lot of material develops during the test.

S10.4 Retests—Retests are only permitted for ash content, graphite purity, bulk density, and detrimental material tests. Retests shall be performed on twice the number of specimens that were originally nonconforming. Retest specimens shall be taken in the vicinity of the initial location of a failed specimen. If any of the retest specimens fail, the lot shall be rejected with no further retesting permitted.

S10.5 Resubmittal of Rejected Lots—A rejected lot shall be resubmitted for acceptance provided that the rejected lot is reworked, as necessary, to correct the nonconforming condition. Reworking shall consist of any procedure required to correct physical, mechanical, or dimensional deficiencies in nonconforming material to meet specification requirements without adversely affecting its other required characteristics.

APPENDIX

(Nonmandatory Information)

X1. RATIONALE

X1.1 This appendix provides general background information for the specification which is an adaptation of the former MIL-P-24503, “Packing Material, Graphitic, Corrugated Ribbon or Textured Tape and Die-Formed Ring.” The intent of this specification is to provide general guidance describing commercial packing requirements in the main body and military ship requirements in the supplementary requirements section. Note that Grade A military (ASTM/DoD) packing is restrictive in terms of the corrosion inhibitor allowed.

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Standard Specification for
Packing Material, Graphitic or Carbon Braided Yarn

This standard is issued under the fixed designation F 2191; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers staple or continuous filament carbon/graphite yarn valve stem compression packing, suitable for use as end-rings on packing systems for valves. Intended services include steam, hydrocarbons, water and non-oxidizing chemicals. Where this specification is invoked as ASTM F 2191, Sections 1-18 apply. Where this specification is invoked as ASTM/DoD F 2191, Sections 1-18 and the Supplementary Requirements are applicable.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
C 135 Test Method for True Specific Gravity of Refractory Materials by Water Immersion
C 561 Test Method for Ash in a Graphite Sample
C 562 Test Method for Moisture in a Graphite Sample
C 816 Test Method for Sulfur in Graphite by Combustion—Iodometric Titration Method
C 889 Test Method for Chemical and Mass Spectrographic Analysis of Nuclear-Grade Gadolinium Oxide (Gd₂O₃) Powder
D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)
D 512 Test Methods for Chloride Ion in Water
D 1179 Test Methods for Fluoride Ion in Water
D 1246 Test Method for Bromide Ion in Water
D 3178 Test Methods for Carbon and Hydrogen in the Analysis Sample of Coal and Coke
D 3684 Test Method for Total Mercury in Coal by the Oxygen Bomb Combustion/Atomic Absorption Method
D 3761 Test Method for Total Fluorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method
D 3951 Practice for Commercial Packaging
D 4239 Test Method for Sulfur in the Analysis Sample of Coal and Coke Using High-Temperature Tube Furnace Combustion Methods

2.2 Military Standards:
MIL-STD-129 Marking for Shipment and Storage
MIL-P-24583 Packing Material, Graphitic or Carbon Braided Yarn
MIL-P-24503 Packing Material, Graphitic, Corrugated Ribbon or Textured Tape and Preformed Ring

2.3 Fluid Sealing Association Handbook:
Guidelines for the Use of Compression Packings, Copyright 1997

3. Terminology

3.1 base fiber density—bulk density of the base fiber before being coated or impregnated and braided into packing; expressed as lb/ft³.

3.2 braided flexible graphite—a braid constructed of continuous strands or strips of expanded flexible graphite tape or ribbons which may have been overwrapped or have imbedded reinforcing fibers.

3.3 carbon fibers—fibers used in braided packing are produced from viscose rayon, pitch, or polyacrylonitrile (PAN) and are defined as a yarn with a carbon assay of less than 99 %.

3.4 carbon yarns—manufactured from continuous or staple carbon fibers that are twisted or plied into continuous individual strands of between 6 and 18 µm in diameter.

3.5 carbon/graphite fibers—carbon/graphite fibers used in braided packing are produced from viscose rayon, pitch, or polyacrylonitrile (PAN).
3.6 *center or corner filler strands*—strands of fiber/yarn that run parallel to the longitudinal axis of the braid in the corners or center to control the internal density and dimensional stability of the braid.

3.7 *continuous*—individual fibers are almost infinite in length.

3.8 *continuous or staple carbon/graphite*—continuous or staple defines the length of the individual fibers in the carbonaceous yarn. Continuous means the fibers are infinite in length and staple means the individual fibers are at least 75 mm (3 in.) long and preferably 150 to 200 mm (6 to 8 in.) long. All of the fibers are between 6 to 18 µm in diameter and are twisted/plied into continuous strands called yarns.

3.9 *corrosion inhibitors*—additives to the yarn or braid to function in a passive or sacrificial manner to reduce galvanic corrosion such as embedded zinc powder, phosphorus, or barium molybdate.

3.10 *detrimental materials*—abrasive or chemically active constituents such as abrasive ash particles (in high ash content foils) or elemental materials as in Table 2.

3.11 *diagonal interlocking braid*—these strands criss-cross from the surface of the braid diagonally through the body of the braid and each strand is strongly locked by other strands to form an integral structure (see Fig. 1).

3.12 *dispersion*—various coatings or impregnants added to the base fibers or braid to facilitate handling, lubricate the fibers, accelerate break-in, or act as blocking agents during use.

3.13 *graphite fibers*—fibers used in braided packing are produced from viscose rayon, pitch, or polyacrylonitrile (PAN) and are defined as a yarn with a carbon assay of 99 % or higher.

3.14 *graphite yarns*—manufactured from continuous or staple graphite fibers that are twisted or plied into continuous individual strands between 6 to 18 µm in diameter.

3.15 *lot*—all finished packing of one size, type, class, and grade produced in a continuous run or at the same time and under essentially the same conditions.

3.16 *PAN*—polyacrylonitrile fibers used as precursors to manufacture carbon/graphite for braided packing.

3.17 *PTFE*—polytetrafluoroethylene. (Warning—Graphitic valve packing containing PTFE has been associated with accelerated valve stem corrosion.)

3.18 *specific gravity*—the ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of distilled water at the same temperature.

3.19 *square plait braid*—the strands in this type of braid interlock in a single plane and do not interlock through the body of the braid (see Fig. 1).

### TABLE 1 Chemical and Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Assay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphitic</td>
<td>99% by mass, min.</td>
<td>13.4</td>
</tr>
<tr>
<td>Carbon</td>
<td>95% by mass, min.</td>
<td>13.4</td>
</tr>
<tr>
<td>Ash</td>
<td>1% by mass, max.</td>
<td>13.5</td>
</tr>
<tr>
<td>Finished Packing (in as-supplied state):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.38 g/cc, min.</td>
<td>13.6</td>
</tr>
<tr>
<td>Moisture content</td>
<td>3%, max.</td>
<td>13.7</td>
</tr>
<tr>
<td>Compression recovery</td>
<td>25%, min.</td>
<td>13.10</td>
</tr>
</tbody>
</table>

TABLE 2 Detrimental Materials (Class 2 only (see 13.8))

<table>
<thead>
<tr>
<th>Element</th>
<th>Maximum Allowable Total Impurity Levels in parts per million (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury (Hg)</td>
<td>10</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>750</td>
</tr>
<tr>
<td>Total halogens (chlorine, bromine, and fluorine)</td>
<td>500</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>250</td>
</tr>
<tr>
<td>Bromine (Br)</td>
<td>250</td>
</tr>
<tr>
<td>Fluorine (F)</td>
<td>250</td>
</tr>
</tbody>
</table>

3.20 *staple carbon/graphite*—individual fibers are at least 75 mm (3 in.) long and preferably 150 to 200 mm (6 to 8 in.) long.

3.21 *unraveling*—a loss of the original braiding shape or dimensions of the cut end extending from the cut for a distance greater than that specified along the axis of the packing.

### 4. Classification

4.1 Classification—The material shall be of the following types, classes, and grades, as specified (see 5.1):

- **Type I**—Continuous carbon or graphite yarn.
- **Type II**—Staple carbon or graphite yarn.
- **Type III**—Braided flexible graphite.

4.1.1 Class 1—For use where detrimental material and lubricant content of the packing need not be controlled beyond normal manufacturing limits.

4.1.2 Class 2—For use where detrimental materials content must be controlled to limits specified herein.

4.1.3 Class 3—For use where detrimental materials content need not be controlled beyond normal manufacturing limits, and media temperatures do not exceed 500°F (260°C).

- **Grade A**—Treated with corrosion inhibitor.
- **Grade B**—No corrosion inhibitor.

### 5. Ordering Information

5.1 Acquisition Requirements—Acquisition documents must specify the following:

- **Title**, number, and date of this specification.
- **Type**, Class and Grade required (see Section 4).
- **Carbon** or graphite.
- **Type** of corrosion inhibitor.
- **Chemical properties** (see 7.1).
- **Inspection**, testing, and certification of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

5.1.1 Title, number, and date of this specification.

5.1.2 Type, Class and Grade required (see Section 4).

5.1.3 Carbon or graphite.

5.1.4 Type of corrosion inhibitor.

5.1.5 Chemical properties (see 7.1).

5.1.6 Inspection, testing, and certification of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

5.1.7 Size required (see 9.1). When pre-cut rings are desired, specify the braid cross-section, inside diameter, outside diameter, and number of rings required.

5.1.8 Put-up, if other than required by Table S4.1 (see Supplementary Requirements).

5.1.9 Application data.

5.1.10 Packaging requirements (see Section 18 and Supplementary Requirements).

5.1.11 Marking requirements (see 17.1 and Supplementary Requirements).

### 6. Materials and Manufacture

6.1 Materials and Manufacture—The material shall be as specified in 6.1.1-6.1.5.
6.1.1 Yarn:
6.1.1.1 Type I packing shall be made of continuous filament carbon or graphite yarn.
6.1.1.2 Type II shall be made of staple carbon or graphite yarn.
6.1.1.3 Type III shall be made of flexible graphite.

6.1.2 Packing:
6.1.2.1 Class 1 packing shall be made of Type I or Type II yarn and shall have a pure graphitic dispersion or carbon dispersion.
6.1.2.2 Class 2 packing shall be made of Type I yarn and shall have a pure graphite or carbon dispersion.
6.1.2.3 Class 3 packing shall be made of Type I or Type II yarn and shall have a pure graphite, or carbon dispersion and may be coated with polytetrafluoroethylene (PTFE) (see 7.2 and 13.9).

6.1.3 Coating and Corrosion Inhibiting Treatments:
6.1.3.1 Grade A—Grade A packing shall be provided with a powdered zinc (Zn) active corrosion inhibiting treatment or a passive inhibiting treatment such as phosphorus or barium molybdate. If required, both active and passive inhibitors shall be used.

6.1.3.2 Grade B—Grade B packing shall not contain corrosion inhibiting additives.

6.1.4 Packing Construction (Type I and Type II)—Packing shall be square (plait) braided for cross-sectional sizes smaller than 6 mm (1/4 in.). Cross-sectional sizes of 6 mm (1/4 in.) or greater shall use a diagonal interlocking type construction. The diagonal interlocking constructions shall consist of either single or plied yarns braided on 12, 18, 20, 24, 32, or 36 carrier braiding machines. Additional axial center, corner, and (stuffer) warp yarn(s) can be added within the braid as necessary to produce a dense square cross-section packing profile with good dimensional stability.

6.1.5 Mercury Exclusion—During manufacturing, fabrication, handling, packaging, and packing, the packing material shall not come in contact with mercury or mercury containing compounds.

7. Properties
7.1 Chemical and Physical Properties—Unless otherwise specified, the properties of the finished packing shall conform to the requirements of Table 1. Class 2 also requires compliance with Table 2.
7.2 PTFE Coating (Class 3 only)—If PTFE is used, it shall not exceed 10 % by mass of the packing (see 13.9) unless otherwise agreed to by the purchaser. (Warning—Graphitic valve packing containing PTFE has been associated with accelerated valve stem corrosion.)

7.3 Prohibited Additions—There shall be no intentional additions of any of the detrimental materials listed in Table 2 or any antimony (Sb), arsenic (As), bismuth (Bi), cadmium (Cd), gallium (Ga), indium (In), lead (Pb), mercury (Hg), silver (Ag), or tin (Sn), or, in the case of Grade B packing, zinc (Zn).

8. Other Requirements

8.1 Braid Geometry Retention—Untaped, cut ends shall not unravel more than 3 mm (1/8 in.) with the packing dry or wet (see 13.11). For example, packing 12 mm (1/2-in.) in cross section shall not unravel more than 3 mm (1/8 in.) at either end of the packing.


9.1 Sizes and Mass—Packing shall be furnished in the sizes shown in Table 3, or other size(s) as is ordered by the customer, (see Section 5 and 6.1.4). Packing shall be formed approximately square or rectangular in cross-section (either when straight or when placed about a shaft) within the dimensional tolerances of Table 3. When specified in the purchase document (see 5.1 and 13.2), the mass per linear foot (or other measure) shall be in accordance with the sizes listed in Table 4. Sizes not listed in Table 4 shall be as agreed between purchaser and manufacturer and specified in Section 5, Ordering Information. Minimum mass per linear foot should be included as a part of the bid and purchase documents.

9.1.1 Tolerance and Measurement Standards—The generally accepted method of measurements in the packing manufacturing environment is a hand held, direct reading, vernier caliper. To ensure concentricity, the inside diameter is measured using a ground dimensional plug gauge and the outside diameter is measured by the above (caliper) while the plug is inserted. Information regarding tolerance and measurement is available in the Guidelines for the Use of Compression Packings published by the FSA.

10. Workmanship, Finish and Appearance

10.1 Workmanship—The packing shall be free of defects that have the potential to affect its serviceability as defined in Table 5.

10.2 Construction—The sample shall be visually examined and confirmed to be of the correct braid construction (square plait braid or diagonal interlocking braid) for the ordered size (see 5.1 and 6.1.4).

<table>
<thead>
<tr>
<th>Cross Section SI</th>
<th>Cross Section IP</th>
<th>Tolerance SI</th>
<th>Tolerance IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 6 mm</td>
<td>Up to 1/4 in.</td>
<td>±0.4 mm</td>
<td>±1/64 in.</td>
</tr>
<tr>
<td>6 to 25 mm, incl</td>
<td>1/4 to 1 in., incl</td>
<td>±0.8 mm</td>
<td>±1/32 in.</td>
</tr>
<tr>
<td>greater than 25 mm</td>
<td>greater than 1 in.</td>
<td>±1.6 mm</td>
<td>±2/32 in.</td>
</tr>
</tbody>
</table>

11. Quality Assurance

11.1 Quality Systems—Manufacturers shall be prepared to document use of a quality system such as compliance with an ISO 9000 series program or similar program.

12. Specimen Preparation

12.1 Specimen Preparation—Buyer and seller shall agree on specimen preparation.

13. Test Methods

13.1 Tests—In the event that tests are required as part of the purchasing requirements 5.1, tests shall be made in accordance with the following tests or by way of alternate methods of analysis with equal to or improved accuracy and precision. The use of an alternate analytical method requires the prior written consent of the purchasing party before acceptance will be allowed.

13.2 Size—Before unbraiding, the size shall be determined by measuring each sample selected for visual examination (see Table 3). A steel rule with 1 mm (1/32 in.) divisions accurate to 1 mm (1/32 in.) or a steel slide caliper with 0.5 mm (1/64 in.) divisions shall be used (see 9.1).

13.3 Mass—The mass shall be determined using a specimen at least 609.6 mm (2 ft) in length for measurement in conjunction with the values of Table 4.

13.4 Carbon Assay—The sample shall be dried to a constant mass at 149 ± 3°C (300 ± 5°F) before testing. For Grade A packing only, the test shall be conducted prior to the corrosion inhibiting treatment or the added mass of the corrosion inhibitor shall be determined and subtracted from the base mass of the sample. The percent carbon shall be based upon mass of the dried sample. This determination shall be made in accordance with Test Methods D 3178 or an alternate method of analysis with equal or improved accuracy and precision (see Table 1).

13.5 Ash Content—The ash content shall be determined in accordance with Test Method C 561 (see Table 1). For Grade A packing only, the test shall be conducted prior to the corrosion inhibiting treatment or the added mass of the corrosion inhibitor shall be determined and subtracted from the base mass of the sample.

13.6 Specific Gravity—This determination shall be made in accordance with Test Method C 135, modified as follows: (Alternative methods of analysis with equal or improved accuracy and precision (see Table 1) can be used upon receipt of prior written consent and approval by the purchaser.)

13.6.1 Preparation for Test Method C 135—A 50 g (1.7637 oz) sample shall be prepared for grinding by unbraiding, cutting, or otherwise reducing the braided packing to pieces not larger than 3 mm (1/8 in.).

NOTE 1—Test Method C 135 uses a water pycnometer test method. Test procedures using a gas pycnometer-based analytical method shall forego the need to reduce of the sample to its fiber state.

13.7 Moisture Content—The moisture content shall be determined in accordance with Test Method C 562 (see Table 1).

13.8 Detrimental Materials Tests—For determination of the detrimental materials listed in Table 2 for Class 2 only, the test
methods of Table 6 or alternate methods of equal or improved accuracy and precision shall be used.

13.9 Analysis for PTFE Coating (Class 3 only)—A 5 g specimen of packing shall be placed in a crucible and heated at 104 ± 6°C (220 ± 6°F) to constant mass (original dry mass) at room temperature. Then the specimen shall be heated at 316 ± 6.5°C (600 ± 10°F) for 24 h, cooled, and the mass determined. The same specimen shall then be heated at 482 ± 16°C (900 ± 25°F) for 3 h, cooled, and the mass determined. After the 482°C (900°F) heating, the crucible mass shall be redetermined without the specimen unless a platinum crucible was used. The new mass of the crucible shall be used to determine the mass of the residue after heating. Heating shall be done in a ventilated hood to avoid exposure to toxic vapors. The percentage of PTFE shall be calculated as follows, based on an average of three determinations (see 7.2).

\[
\text{Percent PTFE} = \frac{100(F - N)}{W}
\]

where:

\( W \) = average original dry mass of specimens after extraction,

\( F \) = average mass of residue in crucibles after heating at 316°C (600°F), and

\( N \) = mass of the crucible.

### Table 4: Sizes and Mass of Packing

<table>
<thead>
<tr>
<th>Nominal Size (mm)</th>
<th>Nominal Size (in.)</th>
<th>Types I and II Minimum Mass (g/linear meter)</th>
<th>Types I and II Minimum Mass (lb/linear ft)</th>
<th>Type III Minimum Mass (g/linear m)</th>
<th>Type III Minimum Mass (lb/linear ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>⅛</td>
<td>6.7</td>
<td>.0045</td>
<td>10.4</td>
<td>.007</td>
</tr>
<tr>
<td>3.8</td>
<td>⅛</td>
<td>10.4</td>
<td>.007</td>
<td>16.4</td>
<td>.011</td>
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<tr>
<td>4.5</td>
<td>⅛</td>
<td>13.4</td>
<td>.009</td>
<td>25.3</td>
<td>.017</td>
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<tr>
<td>5.3</td>
<td>⅛</td>
<td>19.4</td>
<td>.013</td>
<td>34.3</td>
<td>.023</td>
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<td>6</td>
<td>⅛</td>
<td>25.3</td>
<td>.017</td>
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<tr>
<td>6.8</td>
<td>⅛</td>
<td>31.3</td>
<td>.021</td>
<td>55.1</td>
<td>.037</td>
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<tr>
<td>7.6</td>
<td>⅛</td>
<td>38.7</td>
<td>.026</td>
<td>64.0</td>
<td>.043</td>
</tr>
<tr>
<td>8.4</td>
<td>⅛</td>
<td>47.7</td>
<td>.032</td>
<td>76.0</td>
<td>.051</td>
</tr>
<tr>
<td>9</td>
<td>⅛</td>
<td>56.6</td>
<td>.038</td>
<td>90.9</td>
<td>.061</td>
</tr>
<tr>
<td>9.6</td>
<td>⅛</td>
<td>65.5</td>
<td>.044</td>
<td>107.2</td>
<td>.072</td>
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<tr>
<td>10.2</td>
<td>⅛</td>
<td>77.5</td>
<td>.052</td>
<td>119.2</td>
<td>.080</td>
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<tr>
<td>10.8</td>
<td>⅛</td>
<td>87.9</td>
<td>.059</td>
<td>148.9</td>
<td>.100</td>
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<tr>
<td>12</td>
<td>⅛</td>
<td>99.8</td>
<td>.067</td>
<td>165.3</td>
<td>.111</td>
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<tr>
<td>12.8</td>
<td>⅛</td>
<td>113.2</td>
<td>.076</td>
<td>184.7</td>
<td>.124</td>
</tr>
<tr>
<td>14.2</td>
<td>⅛</td>
<td>126.6</td>
<td>.085</td>
<td>195.1</td>
<td>.131</td>
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<td>15</td>
<td>⅛</td>
<td>156.4</td>
<td>.105</td>
<td>238.3</td>
<td>.160</td>
</tr>
<tr>
<td>16.5</td>
<td>⅛</td>
<td>189.2</td>
<td>.127</td>
<td>311.3</td>
<td>.209</td>
</tr>
<tr>
<td>18</td>
<td>⅛</td>
<td>226.4</td>
<td>.152</td>
<td>312.8</td>
<td>.210</td>
</tr>
<tr>
<td>19.5</td>
<td>⅛</td>
<td>265.2</td>
<td>.178</td>
<td>537.7</td>
<td>.361</td>
</tr>
<tr>
<td>21</td>
<td>⅛</td>
<td>306.8</td>
<td>.206</td>
<td>558.6</td>
<td>.375</td>
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<tr>
<td>22.5</td>
<td>⅛</td>
<td>353.0</td>
<td>.237</td>
<td>616.6</td>
<td>.414</td>
</tr>
<tr>
<td>24</td>
<td>⅛</td>
<td>402.2</td>
<td>.270</td>
<td>506.4</td>
<td>.340</td>
</tr>
<tr>
<td>30</td>
<td>⅛</td>
<td>627.1</td>
<td>.421</td>
<td>995.5</td>
<td>.669</td>
</tr>
</tbody>
</table>

### Table 5: Classification of Visual Defects

| Areas of loose weave in braid |
| Frayed braid surface         |
| Clumps of yarn fibers protruding from surface |
| Yarn knots excessively sized or extending beyond the braid surface |
| Uneven or irregular stitch pattern |
| Particulate or extraneous matter on surface |
| Lack of corrosion inhibitor (Grade A only) |

### Table 6: Detrimental Material Tests

<table>
<thead>
<tr>
<th>Element</th>
<th>Preparation/Analysis Test Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine (Cl)</td>
<td>(1) Pyrohydrolysis (ASTM C 889)/Ion Chromatographic Analysis</td>
</tr>
<tr>
<td>Bromine (Br)</td>
<td>(2) ASTM D 129/ASTM D 512</td>
</tr>
<tr>
<td>Fluorine (F)</td>
<td>(3) ASTM D 1246 (for Bromine)</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>(1) High temperature combustion in 100 % Oxygen/Non-Dispersive Infrared Analysis or Ion Chromatographic Analysis</td>
</tr>
<tr>
<td></td>
<td>(2) ASTM D 129/ASTM D 1179</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>(3) ASTM D 4239 Method #3 (sample preparation and analysis)</td>
</tr>
<tr>
<td></td>
<td>(1) High temperature combustion in 100 % Oxygen/Non-Dispersive Infrared Analysis or Ion Chromatographic Analysis</td>
</tr>
<tr>
<td></td>
<td>(2) Direct analysis of volatile elements (Hg) by Emission Spectrographic Method</td>
</tr>
<tr>
<td></td>
<td>(3) Direct analysis of volatile elements by Atomic Absorption per ASTM D 3684</td>
</tr>
</tbody>
</table>
13.10 Compression Recovery—Three specimens, each 44 ± 3 mm (1.750 ± 0.125 in.) long, shall be prepared from the sample and the results of the following test of each specimen averaged for comparison with the compression recovery limit of Table 1.

13.10.1 Center the specimen on a flat plate which is larger than the specimen and has its upper surface perpendicular (±2°) to the load to be applied. Place a flat plate of similar size on top of the specimen so that its lower surface is parallel (±2°) to the upper surface of the bottom plate. The upper plate shall weigh 2.27 ± 0.45 kg (5 ± 1 lb). Both plates shall be rigid and maintained parallel during the testing. After the weight of the upper plate has been applied to the specimen for at least 15 s, measure and record the thickness \( P \) of the preloaded specimen. Several measurements about the circumference of the test plate shall be taken and averaged for this, and subsequent, measurements.

13.10.2 Apply the major load, by either the top or bottom plate, along an axis passing through the center of the specimen in a slow, uniform manner so that the major load is attained within 20 ± 5 s. The major load is that load which will produce a stress of 316.4 kg/cm² ± 10 % (4500 lbs/in.² ± 10 %) on the area of the specimen initially in contact with the lower test plate.

13.10.3 Maintain the major load for at least 60 s and measure and record the thickness \( M \) of the fully loaded specimen.

13.10.4 Immediately remove the major load and after about 60 s measure and record the recovered thickness \( R \) under the original preload.

13.10.5 Calculate the percent compression recovery (PCR) as follows:

\[
\text{PCR} = \left( \frac{R - M}{P - M} \right) \times 100
\]

13.11 Braid Geometry Retention—Cut a 50 ± 1.5 mm (2 ± ½ in.) length packing (the ends shall not be taped prior to or after cutting). Soak the test piece in room temperature water for 15 min, minimum. The packing shall not unravel at the ends more than 3 mm (½ in.) at either end (see 8.1).


14.1 Inspection and testing of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract (see 5.1).

15. Rejection

15.1 Materials that fail to conform to the requirements of this specification shall be rejected. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of testing, the producer shall make claim for a rehearing or provide for third party testing.

16. Certification

16.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been tested and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

16.2 Detrimental Materials Control—For Class 2 material only, the vendor shall provide certification that the limits of Table 2 have been met and that low melting metals (anitmony (Sb), arsenic (As), bismuth (Bi), cadmium (Cd), lead (Pb), tin (Sn), gallium (Ga), indium (In), silver (Ag), mercury (Hg) and zinc (Zn) [zinc for Grade B only]) have not been added as intentional constituents. Instead of specific test results for the lot to be delivered, certifications shall be based on tests of both raw materials and production lots of similar finished packing material over an extended time period (not exceeding three years between tests). Any change to manufacturing processing which affects product composition, including changes to raw material, binders, or inhibitors (Grade A) shall require additional testing to form the basis for future certifications.

17. Product Marking

17.1 Marking—For commercial shipment, marking shall be in accordance with accepted industry practices or as required in the purchase contract (see 5.1). Marking shall include type of corrosion inhibitor, if any.

18. Packaging

18.1 Commercial Packaging—Commercial packaging shall be in accordance with Practice D 3951 or as required in the purchase contract (see 5.1).
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. All of these Supplementary Requirements and Sections 1–18 are applicable where this specification is invoked as ASTM/DoD F 2191. This specification is adapted from MIL-P-24583.

S1. DoD Intended Use

S1.1 Type I packings are intended for general shipboard service as anti-extrusion end-rings to be used in conjunction with corrugated ribbon or preformed ring graphitic packing material in valves. Grade A packing is intended for use in valves with non-corrosion resistant (for example, carbon steel, 400 series stainless steel) stem and packing gland parts.

S2. Classification

S2.1 The Type (I and II) and Class classifications of this specification correspond to the Type and Class classifications of MIL-P-24583.

S2.2 The Grade B classification of this specification corresponds to the Grade N classification of MIL-P-24583.

S2.3 The Grade A classification of this specification, utilizing zinc powder corrosion inhibitor only, corresponds to the Grade I classification of MIL-P-24583.

S3. Materials and Manufacture

S3.1 Coating and Corrosion Inhibiting Treatments:

S3.1.1 Grade A—Grade A packing shall be provided with a powdered zinc (Zn) active corrosion inhibiting treatment only (2 % zinc, by weight, minimum).

S3.1.2 Grade B—Grade B packing shall not contain corrosion inhibiting additives.

S4. Dimensions and Tolerances

S4.1 Put-Up—Unless otherwise specified (see Section 5), packing shall be uniformly coiled on spools or reels of the size specified (see Section 5) in accordance with Table S4.1. No more than three segments of packing shall be provided on the smallest spool or reel.

S5. Quality Assurance

S5.1 As a minimum, manufacturers shall provide and maintain an inspection system that meets the requirements of ANSI/ASQC Q9003.

S6. Test Methods

S6.1 Examination for Visual and Dimensional Defects—Units shall be examined for visual and dimensional defects as follows:

S6.1.1 Size—The size of each unit selected shall be measured for conformance with the requirements of Section 9, including Table 3, and 13.2.

S6.1.2 Visual Examination—Each unit selected shall be visually examined to determine conformance with the requirements of 10.1, including Table 5.

S6.1.3 Construction—Each unit selected shall be visually examined to determine conformance with the requirements of 10.2.

S6.2 Examination for Preparation for Delivery—Each unit selected shall be visually examined to determine compliance with packaging requirements (see Sections 5 and 18) and marking requirements (see Sections 5 and 9).

S6.3 Simulated Performance—The test shall be conducted in an apparatus designed to simulate conditions in valves in actual service. A schematic of the test rig is shown in Fig. S6.1. The valves used in the simulator shall have glands and stems that are in new condition. The entire piping system and valves shall be insulated so as to minimize heat loss. Thermocouples shall be installed so as to indicate the actual steam temperature. The simulator shall be capable of holding a temperature of 524 ± 14°C (975 ± 25°F) and a pressure of 84 ± 3.5 kg/cm² (1200 ± 50 lb/in.²) for the duration of the test. The packing shall be installed and the gland initially adjusted so that no leakage occurs with the system at its operating temperature and pressure.

<table>
<thead>
<tr>
<th>Packing Size, mm</th>
<th>Packing Size, in.</th>
<th>Package, (net mass in kg)</th>
<th>Package, (net mass in lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 through 8.7</td>
<td>⅛ through ⅛⅞</td>
<td>0.45, 0.9 or 1.35 kg spools</td>
<td>1, 2, or 3 lb spools</td>
</tr>
<tr>
<td>9.5 through 15.1</td>
<td>⅜ through ⅞</td>
<td>0.9, 1.35, or 2.28 kg spools</td>
<td>2, 3, or 5 lb spools</td>
</tr>
<tr>
<td>15.9</td>
<td>⅛</td>
<td>1.35, 2.28, 4.54 or 11.4 kg reels</td>
<td>3, 5, 10, or 25 lb reels</td>
</tr>
<tr>
<td>17.5</td>
<td>⅛⅞</td>
<td>1.35, 2.28, 4.54 or 11.4 kg reels</td>
<td>3, 5, 10, or 25 lb reels</td>
</tr>
<tr>
<td>19.0</td>
<td>⅛</td>
<td>2.28, 4.54 or 11.4 kg reels</td>
<td>5, 10, or 25 lb reels</td>
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<tr>
<td>20.6</td>
<td>⅞</td>
<td>2.28, 4.54 or 11.4 kg reels</td>
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<tr>
<td>22.2</td>
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<td>2.28, 4.54, 11.4 or 22.7 kg reels</td>
<td>5, 10, 25, or 50 lb reels</td>
</tr>
<tr>
<td>23.8</td>
<td>1</td>
<td>2.28, 4.54, 11.4 or 22.7 kg reels</td>
<td>5, 10, 25, or 50 lb reels</td>
</tr>
<tr>
<td>25.4</td>
<td>1</td>
<td>4.54, 11.4 or 22.7 kg reels</td>
<td>10, 25, or 50 lb reels</td>
</tr>
<tr>
<td>31.8</td>
<td>1⅛</td>
<td>4.54, 11.4 or 22.7 kg reels</td>
<td>10, 25, or 50 lb reels</td>
</tr>
</tbody>
</table>
pressure. The valve shall be fully cycled manually not less than once every half-hour (full close to full open). The following schedule shall be followed for running the test (test need not be conducted over a weekend period, if desired):

- 12 days at temperature 524°C (975°F) and 84.35 kg/cm² (1200 ± 50 lb/in.²) pressure
- 35 ± 5 days at ambient temperature and pressure (system shut down; valves need not be cycled)
- 5 days at 524°C (975°F) and 84 ± 3.5 kg/cm² (1200 ± 50 lb/in.²) pressure

There shall be no steam leakage from the packing gland during the simulated performance test at a temperature of 524°C (975°F) and a pressure of 84 ± 3.5 kg/cm² (1200 ± 50 lb/in.²). There shall also be no corrosion or degradation of the packing gland at the completion of the test. Any leakage or gland adjustment shall be recorded. This test is equivalent to the simulated performance test of MIL-P-24503.

S7. Inspection and Testing

S7.1 Unless otherwise specified (see Section 5), first article testing and quality conformance testing are required. The inspections and tests making up the first article and quality conformance testing are as follows:

S7.2 First Article Tests—First article testing shall consist of the examinations and tests of Table S7.1.

### TABLE S7.1 First Article and Quality Conformance Tests

<table>
<thead>
<tr>
<th>First Article Tests</th>
<th>Quality Conformance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examination for visual and dimensional defects</td>
<td>9, 10, 13.2</td>
</tr>
<tr>
<td>Mass</td>
<td>9.1</td>
</tr>
<tr>
<td>Carbon assay</td>
<td>Table 1</td>
</tr>
<tr>
<td>Ash</td>
<td>Table 1</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>Table 1</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Table 1</td>
</tr>
<tr>
<td>Detrimental materials (Class 2 only)</td>
<td>Table 1</td>
</tr>
<tr>
<td>PTFE coating</td>
<td>7.2</td>
</tr>
<tr>
<td>Compression recovery</td>
<td>Table 1</td>
</tr>
<tr>
<td>Braid geometry retention</td>
<td>8.1</td>
</tr>
<tr>
<td>Simulated performance</td>
<td>Table 1</td>
</tr>
<tr>
<td>Examination for preparation for delivery</td>
<td>N/A</td>
</tr>
</tbody>
</table>

S7.3 Quality Conformance Tests—Quality conformance testing shall be in accordance with Table S7.1.

S7.4 Sampling:

S7.4.1 Sampling for Visual and Dimensional Examination (S6.1)—As a minimum, the contractor shall randomly select a quantity of sampling units from each lot of graphitic or carbon braided yarn packing material in accordance with Table S7.2 and subject them to the examinations for visual and dimensional defects of S6.1. The sample size depends on the lot size. If one or more defects are found in any sample, the entire lot shall be rejected. The contractor has the option of screening 100% of the rejected lot for the defected characteristics or providing a new lot, which shall be selected in accordance with the sampling plan herein. The contractor shall maintain for a period of three years after contract completion, records of inspections, tests, and any resulting rejections.

S7.4.2 Sampling for Chemical and Physical Property and Detrimental Material Tests—A single random sample shall be selected from each lot for the testing of 13.3-13.11.

S7.4.3 Sampling for Examination for Preparation for Delivery (S6.2)—The lot size shall be the number of shipping containers. Sampling shall be in accordance with Table S7.2.

S7.4.4 Sampling for Simulated Performance Test (S6.3)—A sample of sufficient size shall be selected for the simulated performance test.

S8. Certification

S8.1 Simulated Performance Test—After the simulated performance test is once performed acceptably, providing product
composition and processing has not been changed, a certificate of compliance, citing the test report or document accepting compliance with the test requirement, shall be provided thereafter.

S9. Product Marking

S9.1 Minimum Product Marking—Item description marking shall include, as a minimum, the size, type, class, grade and type of inhibitor (if any) of the packing material. In addition, the item description marking shall include the phrase “ASTM/DoD F 2191” to identify the applicability of this specification and any special marking which may be required, such as bar coding (see Section 5). Marking for DoD procurements shall be in accordance with MIL-STD-129.

S9.2 Spool/Reel Marking—If packing is to be provided on spools or reels, the required information of S9.1, and the National Stock Number and contract number, shall be marked on the spool or reel.

S10. Rejection

S10.1 Known Defects—Materials that fail to conform to the requirements of this specification shall not be offered for delivery.

S10.2 Buyer Testing—The buyer reserves the right to perform any of the inspections and tests set forth in this specification. Materials that fail to conform to the requirements of this specification shall be rejected. Rejection will be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of testing, the producer shall make claim for a rehearing or provide for third party testing.

S10.3 Replacement of Test Specimens—A test specimen shall be discarded and a replacement specimen selected from the same lot of material under the following conditions:

S10.3.1 Where the specimen is incorrectly prepared.
S10.3.2 Where the test procedure is incorrect.
S10.3.3 Where there is a malfunction of the testing equipment.
S10.3.4 Where a flaw that is not indicative of an inferior or defective lot of material develops during the test.

S10.4 Retests—Retests are only permitted for ash content, graphite purity, bulk density and detrimental material tests. Retests shall be performed on twice the number of specimens that were originally nonconforming. Retest specimens shall be taken in the vicinity of the initial location of a failed specimen. If any of the retest specimens fail, the lot shall be rejected with no further retesting permitted.

S10.5 Resubmittal of Rejected Lots—A rejected lot can be resubmitted for acceptance provided that the rejected lot is reworked, as necessary, to correct the nonconforming condition. Reworking shall consist of any procedure required to correct physical, mechanical or dimensional deficiencies in nonconforming material to meet specification requirements without adversely affecting its other required characteristics.

APPENDIX

(Nonmandatory Information)

XI. RATIONALE (COMMENTARY)

This appendix provides general background information for this specification, which is an adaptation of the former MIL-P-24583, “Packing Material, Graphitic or Carbon Yarn.” The intent of this specification is to provide general guidance describing commercial packing requirements in the main body and military ship requirements in the supplementary requirements section. It is noted that some Grade A military ASTM/DoD packings are restrictive in terms of the corrosion inhibitors.

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Standard Test Method for Determining and Reporting the Berthing Energy and Reaction of Marine Fenders

This standard is issued under the fixed designation F 2192; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

A marine fender is an energy-absorbing device that is typically secured against the face of a marine facility or a ship’s hull for the purpose of attenuating the forces inherent in arresting the motion of berthing vessels safely. Most modern fenders fall into three general classifications based on the material used to absorb energy: (1) solid rubber fenders in which the material absorbs the energy, (2) pneumatic (air-filled) fenders in which air absorbs the energy, and (3) foam-filled fenders in which the foam core absorbs the energy.

1. Scope

1.1 This test method establishes the recommended procedures for quantitative testing, reporting, and verifying the energy absorption and reaction force of marine fenders. Marine fenders are available in a variety of basic types with several variations of each type and multiple sizes and stiffnesses for each variation. Depending on the particular design, marine fenders may also include integral components of steel, composites, plastics, or other materials. All variations shall be performance tested and reported according to this test method.

1.2 There are three performance variables: berthing energy, reaction, and deflection. There are two methods used to develop Rated Performance Data (RPD) and published performance curves for the three performance variables.

1.3 The primary focus is on fenders used in berthing and ship-to-ship applications for marine vessels. This testing protocol does not address small fendering “bumpers” used in pleasure boat marinas, mounted to hulls of work boats, or used in similar applications; it does not include durability testing. Its primary purpose is to ensure that engineering data reported in manufacturers’ catalogues are based upon common testing methods.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Significance and Use

3.1 General:

3.1.1 All testing shall define fender performance under velocities that decrease linearly or that are proportional to the square root of percent of remaining rated energy.

3.1.2 Rated performance data (RPD) and manufacturers’ published performance curves or tables, or both, shall be based on: (1) initial deflection (berthing) velocity of 0.15 m/s and decreasing to no more than 0.005 m/s at test end, (2) testing of fully broken-in fenders (break-in testing is not required for pneumatic fenders), (3) testing of fenders stabilized at 23 ± 5°C (excluding pneumatic fenders; see 6.3), (4) testing of fenders at 0° angle of approach, and (5) deflection (berthing) frequency of not less than 1 h (use a minimum 5-min deflection frequency for pneumatic fenders.).

3.1.3 Catalogues shall also include nominal performance tolerances as well as data and methodology to adjust performance curves or tables or both for application parameters different from RPD conditions. Adjustment factors shall be provided for the following variables: (1) other initial velocities: 0.05, 0.10, 0.20, 0.25, and 0.30 m/s; (2) other temperatures: +50, +40, +30, +10, 0, −10, −20, −30; and (3) other contact angles: 3, 5, 8, 10, 15°. In addition, RPD shall contain a cautionary statement that published data do not necessarily apply to constant-load and cyclic-loading conditions. In such cases, designers are to contact fender manufacturers for design assistance.

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1 This test method is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.


3.1.4 Adjustment factors for velocity and temperature shall be provided for every catalogue compound or other energy absorbing material offered by each manufacturer.

3.2 Fender Testing—Performance testing to establish RPD must use either one of two methods:

3.2.1 Method A—Deflection of full-size fenders at velocities inversely proportional to either (1) the percent of either (a) rated deflection or (b) remaining rated energy or (2) the square root of the percent of rated energy absorbed. Test parameters shall be as defined for published RPD. RPD tests shall start at 0.15 m/s. Tests to establish adjustment factors for initial berthing velocities other than 0.15 m/s shall start at those other initial velocities.

3.2.2 Method B—Deflection of full size fenders at constant velocity with performance adjusted by velocity factors developed from model tests. Velocity factors shall be the ratio of performance test results of models under the following conditions: (1) a constant strain rate similar to the strain rate of the full-size fender at its test speed, and (2) decreasing speed deflection with initial strain rate similar to that of the full-size fender under RPD deflection conditions.

3.2.3 The RPD for pneumatic fenders shall be determined using either Method A or Method B with miniature-size fenders; in which case, the compression performance of air shall be directly extrapolated from the test data of reduced scale models.

4. Apparatus

4.1 The test apparatus shall be equipped with load cell(s) and linear transducer(s) capable of providing continuous monitoring of fender performance. The test apparatus shall be capable of recording and storing load-cell and transducer data at intervals of <0.01 H, where H is a fender’s nominal height, and storing manually entered inputs. Output information shall include, as a minimum:

4.1.1 Serial number and description of test item,
4.1.2 Date, time at start, and time at end of test,
4.1.3 Location of test facility and test apparatus ID,
4.1.4 Stabilization temperature of test specimen,
4.1.5 Test ambient temperature, and
4.1.6 Graphic plot(s) of: (1) deflection velocity versus deflection (optional) (If not plotted, deflection velocity and its characteristics shall be separately noted.), (2) reaction versus deflection, and (3) energy versus deflection.

4.2 For fender tests, all equipment used to measure and record force and deflection shall be calibrated and certified accurate to within ±1%, in accordance with ISO or equivalent JIS or ASTM requirements. Calibration shall be performed within one year of the use of the equipment, or less, if the normal calibration interval is shorter than one year. Calibration of test apparatus shall be performed by a qualified third-party organization, using instrumentation that is traceable to a certified, national standard.

4.3 The test apparatus shall deflect specimens according to Section 5.

5. Procedure

5.1 The performance test shall deflect specimens according to either of the two methods listed below. Clear and unambiguous calculations must be provided for any adjustments made to the test results.

5.2 Method A:

NOTE 1—Steps 5.2.1 and 5.2.2 do not apply to pneumatic fenders. Step 5.2.3 may be omitted for pneumatic fenders, provided internal pressure is adjusted to the manufacturer’s specified value for the ambient test temperature.

5.2.1 Break in the specimen by deflecting it three or more times to its rated deflection, or more, as recommended by the manufacturer.

5.2.2 Remove load from specimen and allow it to “recover” for 1 h or more, as recommended by manufacturer.

5.2.3 Before conducting performance test, stabilize fender temperature in accordance with 6.1. Temperature-stabilizing time can include time for 5.2.1 and 5.2.2.

5.2.4 Deflect specimen once at a continuously decreasing deflection velocity as defined in one of the equations below:

\[ V = V_0 \frac{(D - d)}{D} \text{ or } 0.005 \text{ m/s whichever is greater} \quad (1) \]

or

\[ V = V_0 \sqrt{(E - e)/E} \text{ or } 0.005 \text{ m/s whichever is greater} \quad (2) \]

where:

- \( V \) = instantaneous deflection velocity of fender,
- \( V_0 \) = initial deflection velocity, where \( V_0 = 0.05, 0.10, 0.15, 0.20, 0.25, \) or \( 0.30 \) m/s,
- \( D \) = rated deflection,
- \( d \) = instantaneous deflection,
- \( E \) = rated energy absorption of fender, and
- \( e \) = instantaneous running total of energy absorbed.

Initial velocity shall be appropriate for particular testing purpose.

5.2.5 Stop test when deflection reaches rated deflection, or more, as recommended by the manufacturer.

5.2.6 Adjust performance to rating temperature (23 ± 5°C), if required, or to desired application temperature by multiplying both energy and reaction results by temperature factor (TF) (see 6.3).

5.3 Method B:

NOTE 2—Steps 5.3.1 and 5.3.2 do not apply to pneumatic fenders. Step 5.3.3 may be omitted for pneumatic fenders, provided internal pressure is adjusted to the manufacturer’s specified value for the ambient test temperature.

5.3.1 Break in specimen by deflecting three or more times to its rated deflection, or more, as recommended by the manufacturer.

5.3.2 Remove load from specimen and allow it to “recover” for 1 h or more, as recommended by manufacturer.

5.3.3 Before conducting performance test, stabilize fender temperature in accordance with 6.1. Temperature-stabilizing time can include time for 5.3.1 and 5.3.2.

5.3.4 Deflect specimen once at a constant deflection velocity.

5.3.5 Stop test when deflection reaches rated deflection, or more, as recommended by the manufacturer.
5.3.6 Adjust performance to rated temperature (23 ± 5°C), if required, or to desired application temperature by multiplying both energy and reaction results by temperature factor (TF) (see 6.3).

5.3.7 Adjust performance to RPD initial deflection velocity (0.15 m/s) or to desired initial berthing velocity, if required, by multiplying both energy and reaction results by velocity factor (VF) (see 6.2).

6. Supporting Procedures

6.1 Temperature Stabilization:

6.1.1 Test temperature for full-size specimens is defined as the same as stabilization temperature, as long as ambient temperature at test apparatus is within ±15°C of stabilization temperature and testing is completed within 2 h of the specimen’s removal from the temperature-controlled environment.

6.1.2 To stabilize temperature, store specimen at a constant temperature ±5°C. Record air temperature of space where specimen is stored within 3 m of specimen surface, either continuously or twice a day, no less than 10 h apart.

6.1.3 Stabilization time shall be not less than 20x 1.5 days or more as recommended by the manufacturer, rounded to the next whole day (x = dimension of greatest rubber thickness, in meters), after curing plus 20x 1.5 days, rounded to the next whole day, after being in an ambient temperature differing from stabilization temperature by more than 10°C for more than 8 h.

6.2 Velocity Factor (VF)—One of the following protocols shall be followed to determine VF for every combination of fender configuration, initial velocity other than RPD velocity, fender element standoff and energy-absorbing material. Specimens for determining VF may be either full-size fenders or models, as noted below. Pneumatic fenders do not require a VF.

6.2.1 Method A—Testing of full-size fenders at actual, decreasing rate deflection velocity.

6.2.1.1 Test full-size fenders per 5.2 at 0.15-m/s initial velocity and 23 ± 5°C.

6.2.1.2 Repeat at other initial velocities.

6.2.1.3 Derive the VFs from the data in 6.2.1.1 and 6.2.1.2 per the following method:

1. Energy velocity factor and reaction velocity factor by Method A, VF<sub>ea</sub> and VF<sub>ra</sub>, shall be defined by the following equations:

\[ VF_{ea} = \frac{E_a}{E_{RPD}} \]
\[ VF_{ra} = \frac{R_a}{R_{RPD}} \]

where:
- \( E_a \) = energy at alternative initial velocity,
- \( R_a \) = reaction at alternative initial velocity,
- \( E_{RPD} \) = energy at RPD initial velocity, and
- \( R_{RPD} \) = reaction at RPD initial velocity.

6.2.2 Method B—Testing of model at both constant and decreasing strain rates.

6.2.2.1 Calculate the strain rate of the full-size fender when it is deflected at the constant velocity of 0.0003 to 0.0013 m/s (2 to 8 cm/min).

6.2.2.2 Test the model, per 5.3, at 23 ± 5°C, at the strain rate calculated in 6.2.2.1 (± 10%).

6.2.2.3 Calculate the initial strain rate of the full-size fender when it is deflected at the desired initial berthing velocity.

6.2.2.4 Test the same model used in 6.2.2.2 per 5.3, at 23 ± 5°C, beginning at the initial strain rate calculated in 6.2.2.3 (±10%).

6.2.2.5 Derive velocity factors for energy and reaction, VF<sub>e</sub> and VF<sub>r</sub>, from the data in 6.2.2.2 and 6.2.2.4 per the following equations:

\[ VF_e = R_e/R_{test} \]
\[ VF_r = E_r/E_{test} \]

where:
- \( E_e \) = energy per 6.2.2.4,
- \( E_{test} \) = energy per 6.2.2.2,
- \( R_e \) = reaction per 6.2.2.4, and
- \( R_{test} \) = reaction per 6.2.2.2.

6.3 Temperature Factor (TF)—Temperature factors (TF) for pneumatic fenders may be calculated using ideal gas laws. For every urethane, foam or rubber compound, the TFs shall be determined by the following procedure.

6.3.1 Conduct standard performance tests on temperature-stabilized specimens using either Method A or Method B, per one of the two methods described below:

6.3.1.1 (A)—Stabilize specimens at test temperature per 6.1.2 and 6.1.3. Specimens shall be either full-size fenders or models not smaller than 0.1 m in height. Test specimens in test apparatus maintained at test temperature for duration of test.

6.3.1.2 (B)—Stabilize specimens at test temperature per 6.1.2 and 6.1.3. Specimens shall be either full-size fenders or models not smaller than 0.3 m in height. Test specimens at room temperature. Test must be completed within 15 min of sample’s removal from temperature-controlled environment.

6.3.2 Specimens shall be stabilized at the following temperatures: -30, -20, -10, 0, +10, +23, +30, +40, and +50°C. The TFs for each of these temperatures, TF<sub>t</sub>, where \( t \) is the number designating the reference temperature, shall then be calculated by the following equations:

\[ TF_t = R_t/R_{23} \]
\[ TF_{23} = E_{23}/E_{23} \]

where:
- \( R_t \) = reaction at temperature other than 23°C (highest reaction below 0.35 H deflection),
- \( R_{23} \) = reaction at 23°C (highest reaction below 0.35 H deflection),
- \( E_t \) = energy at temperature other than 23°C, and
- \( E_{23} \) = energy at 23°C.
7. Verification/Quality Assurance Testing

7.1 Energy/Reaction Compliance Testing—Verification/quality assurance testing to determine compliance with either RPD or other customer-specified energy and reaction requirements (required performance) shall be performed in a test apparatus, as described in Section 4. Samples for verification testing shall be actual fender elements fabricated for the project location. For cylindrical foam, pneumatic, and hydropneumatic fenders larger than 1800-mm diameter by 3600-mm long, the tests of a 1200-mm diameter by 2000-mm long or larger fender may be scaled to demonstrate the energy and reaction ratings of the fender. The projected fender and the test fender shall both be constructed with the same materials, have the same general configurations of the ends, and have the same skin thickness-to-diameter ratio. Scaling shall be conducted per the following equations:

\[
\text{Energy} = \frac{\text{test fender energy} \times \text{diameter ratio squared} \times \text{overall length ratio}}{\text{test fender reaction} \times \text{diameter ratio} \times \text{overall length ratio}}
\]

7.1.1 Test sample according to Method A (5.2) or Method B (5.3), adjusting performance to required performance as specified in 5.2.6 or 5.3.6, and 5.3.7.

7.1.2 A fender provides the required performance (required energy and reaction) within production tolerances if it meets both the following requirements simultaneously at any point during the test described in 7.1.1:

7.1.2.1 Velocity-and-temperature-adjusted energy absorbed is equal to or greater than the required energy multiplied by the nominal energy tolerance (low end) specified in its catalogue data.

7.1.2.2 Velocity-and-temperature-adjusted reaction is no more than the required reaction multiplied by the nominal reaction tolerance (high end) specified in its catalogue data.

7.2 Other Testing—Other testing requirements, including selection of sampling scheme, shall be as agreed between customer and fender manufacturers.

8. Effect of Contact Angle Testing

8.1 Manufacturers shall include graphs or tables defining the effect of deflecting fenders at the contact angles listed in 3.1.3 (3). This data may be generated mathematically or by testing performed on either actual fender elements or on scale models or arrays. It must reflect the effect of angle contact on an entire fender assembly, not just an individual element.

8.2 The following is the procedure for defining the effect of each contact angle/configuration combination. The test shall be made on the horizontal and vertical axes of the fender unit:

8.2.1 Using a test apparatus as described in Section 4, execute the steps of the test procedure defined in 5.2 or 5.3.

8.2.2 Determine the base-case energy rating for 0° contact angle of the specimen at the deflection or reaction limit recommended by the manufacturer.

8.2.3 Allow the specimen to recover outside the test apparatus for at least 1 h or more as recommended by the manufacturer.

Note: A 5-min recovery period is sufficient for pneumatic fenders.

8.2.4 Attach a “wedge” to the test apparatus’ moveable surface to simulate the desired contact angle and repeat the test cycle only of 8.2.1.

8.2.5 Determine the energy rating of the specimen in the contact angle test at the manufacturer’s recommended deflection or reaction limit.

8.2.6 The contact-angle factor is the energy determined in 8.2.5 divided by that determined in 8.2.2.

8.3 This factor is applied to energy only. No factor need be applied to reaction, since the maximum reaction is as defined by the 0° contact-angle performance. For combined horizontal and vertical contact angles, multiply the contact-angle factor for the horizontal direction by the contact-angle factor for the vertical direction.

9. Precision and Bias

9.1 No information is presented about either the precision or bias of Test Method F 2192 measuring the performance of fenders. The precision and bias information is being determined and will be available on or before May 2006 following Practice E 691.

10. Keywords

10.1 berthing; berthing energy; deflection; energy absorption; fender; fender testing; rated performance data; reaction; temperature factor; velocity factor
1. Scope

1.1 This guide provides assistance in the choice of computing hardware resources for ship and marine environments and describes:

1.1.1 The core characteristics of interoperable systems that can be incorporated into accepted concepts such as the Open System Interconnection (OSI) model;

1.1.2 Process-based models, such as the Technical Reference Model (TRM), that rely on interoperable computing hardware resources to provide the connection between the operator, network, application, and information; and,

1.1.3 The integrated architecture that can be used to meet minimum information processing requirements for ship and marine environments.

1.2 The use of models such as OSI and TRM provide a structured method for design and implementation of practical shipboard information processing systems and provides planners and architects with a roadmap that can be easily understood and conveyed to implementers. The use of such models permit functional capabilities to be embodied within concrete systems and equipment.

1.3 The information provided in this guide is understood to represent a set of concepts and technologies that have, over time, evolved into accepted standards that are proven in various functional applications. However, the one universal notion that still remains from the earliest days of information processing is that technological change is inevitable. Accordingly, the user of this guide must understand that such progress may rapidly invalidate or supersede the information contained herein. Nonetheless, the concept of implementing ship and marine computing systems based on these functional principles allows for logical and rational development and provides a sound process for eventual upgrade and improvement.

2. Referenced Documents

2.1 ASTM Standards:

   E 1013 Terminology Relating to Computerized Systems
   F 1757 Guide for Digital Communications Protocols for Computerized Systems

2.2 ANSI Standards:

   X3.131 Information Systems—Small Computer Systems Interface-2 (SCSI-2)
   X3.172 American National Standard Dictionary for Information Systems
   X3.230 Information Systems—Fibre Channel—Physical and Signaling Interface (FC-PH)
   X3.232 Information Technology—SCSI-2 Common Access Method Transport and SCSI Interface Module
   X3.253 Information Systems—SCSI-3 Parallel Interface (SPI)
   X3.269 Information Technology—Fibre Channel Protocol for SCSI
   X3.270 Information Technology—SCSI-3 Architecture Model (SAM)
   X3.276 Information Technology—SCSI-3 Controller Commands (SCC)
   X3.277 Information Technology—SCSI-3 Fast-20
   X3.292 Information Technology—SCSI-3 Interlocked Protocol (SIP)
   X3.294 Information Technology—Serial Storage Architecture—SCSI-2 Protocol (SSA-S2P)
   X3.297 Information Systems—Fibre Channel—Physical and Signaling Interface-2 (FC-PH2)
   X3.301 Information Technology—SCSI-3 Primary Commands (SPC)
   X3.304 Information Technology—SCSI-3 Multimedia Commands (MMC)
   MS58 Information Technology—Standard Recommended Practice for Implementation of Small Computer Systems Interface (SCSI-2), (X3.131.994) for Scanners
   NCITS 306 Information Technology—Serial Storage Architecture—SCSI-3 Protocol (SSA-S3P)
   NCITS 309 Information Technology—SCSI-3 Block Commands (SBC)

2.3 IEEE Standards:

   100 Standard Dictionary for Electrical and Electronic Terms
   488 Digital Interface for Programmable Instrumentation

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1 This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.05 on Computer Applications.


5 Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331.
6.10.7 Standard Glossary for Computer Networking Terminology
796 Microcomputer System Bus
802.11 Wireless LAN Medium Access Control and Physical Layer Specifications
1003.2d POSIX—Part 2 Shell and Utilities—Amendment: Batch Environment
1003.5 Binding for System Application Program Interface (API)
1003.b Binding for System Application Programming Interface (API)—Amendment 1: Real-time Extensions
1014 Versatile Backplane Bus: VMEbus
1101.10 Additional Mechanical Specifications for Microcomputers using the IEEE Std 1101.1 Equipment Practice
1155 VMEbus Extensions for Instrumentation: VXIbus
1212.1 Communicating Among Processors and Peripherals Using Shared Memory (Direct Memory Access DMA)
1394 High Performance Serial Bus
1496 Chip and Module Interconnect Bus: Sbus
1394 32-bit Microprocessor Architecture
2.4 ISO Standards:
1155 Portable Operating System Interface for Computer Environments (POSIX)
9945-1 System Application Program Interface (API) [C language]
9945-2 Shell and Utilities
2.5 TIA/EIA Standard:
568-A Commercial Building Telecommunications Cabling Standard

3. Significance and Use

3.1 This guide is aimed at providing a general understanding of the various types of hardware devices that form the core of information processing systems for ship and marine use. Ship and marine information processing systems require specific devices in order to perform automated tasks in a specialized environment. In addition to providing information services for each individual installation, these devices are often networked and are capable of supplementary functions that benefit ship and marine operations.

3.2 A variety of choices exists for deployment of information processing devices and greatly increases the complexity of the selection task for ship and marine systems. The choice of a particular device or system cannot be made solely on the singular requirements of one application or function. Modern information processing systems are usually installed in a complex environment where systems must be made to interact with each other. Ship and marine installations add an even further layer of complexity to the process of choosing adequate computerized systems. This guide aims to alleviate this task by giving users specific choices that are proven technologies that perform in a complex environment.

3.3 Hardware resources used in ship and marine installations are a result of careful consideration of utility and function. These resources may require some physical special-
expensive and tailored to the user’s individual preference because application interoperability will not be a significant factor.

4.5 Today, however, most application software is hosted on the client and interoperability among clients is a critical factor. Even within the client-server application architecture, application specific software resident on the client is still prevalent. This demands consistency of client workstations across an entire installation to achieve seamless interoperability. Table 1 outlines a rationale for the client-server deployment strategy.

4.6 Driven by the current state of client-server technology, the general philosophy for implementing computing resources is the concept of homogeneous clients and heterogeneous servers. Homogeneous clients facilitate providing a consistent interface between the user and the system and make system support and maintenance less complex. Heterogeneous servers support the various computing requirements of applications needed to support ship and marine operations. The same advantages that homogeneous clients enjoy can be achieved if servers are homogeneous as well. Independent of whether or not the server suite employed is heterogeneous or homogeneous, it is important that they perform their function transparently to the user (that is, the user neither knows nor cares about the location, number, or vendor of the server being used.) Requiring servers to be homogeneous would restrict the introduction of new server technology, choking innovation and preventing the installation from taking advantage of advances in computing such as massively parallel processors.

5. Computing Hardware

5.1 Computing Resources—Computing resources consist of many computing hardware components and configurations of these components. This section covers the various hardware components that make up a computing resource system and examines how these components are commonly configured.

<table>
<thead>
<tr>
<th>TABLE 1 Client-Server Deployment Rationale</th>
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</thead>
<tbody>
<tr>
<td><strong>Rationale for Heterogeneous Servers</strong></td>
</tr>
<tr>
<td>The server must be tailored to the specific application that may not be supportable by computers most prevalent in the marketplace. Many applications work well in their current computing environment and it is not cost effective to change. It is not practical to have all applications on a common server for multiple reasons including the need to maintain competition between computer developers and vendors. Encourages innovation by not restricting the type of computer used for the development of applications. Allows for a common, consistent user interface. Maximizes interoperability.</td>
</tr>
<tr>
<td><strong>Rationale for Homogeneous Clients</strong></td>
</tr>
<tr>
<td>Minimizes re-training required as users transfer to different organizations within the enterprise. Maximizes the ability to use common support and maintenance skills, parts and labor; thereby minimizing cost. Maximizes portability of support for applications across the enterprise as well as portability of user skills. Allows for economies of scale in both procurement (volume discounts) and support (more focused skill set for help desk personnel).</td>
</tr>
</tbody>
</table>
5.2 Component Technologies—The major hardware components of Computing Resources are the Central Processing Unit (CPU), one or more backplane buses, main memory (both RAM and cache), Input/Output (I/O) interfaces, and peripherals. This section will examine each of these areas and provide guidance on the selection of these component technologies as part of a computing resource system.

5.2.1 CPU—The CPU is the “engine” of the computer system and, combined with the OS (operating system), forms the core of the computing resource. Since the OS drives many decisions concerning the computer resource, a CPU that is compatible with the OS becomes an overriding factor in determining the type of CPU. Other than the OS, the main factors to consider in determining the type of CPU for the computer are processing speed (performance) and cost. For computing resources, such as servers and multiprocessors, scalability of the number of processors can be a significant factor in determining CPU.

5.2.2 Bus—The computer bus connects the different components of the computer resource together and allows them to pass data between them at high speeds. Computer resource configurations, such as personal workstations, often limit or determine the type of bus that will be used. Often there are multiple buses connected together to allow for multiple types of component cards or to extend a non-expandable system bus. Considerations in determining the type of bus to use are: number and type of commercial products compatible with the bus architecture, number of parallel data bit lines, clock speed, and cost. Once the appropriate bus architecture is determined, an important computer resource factor becomes how many interface slots are available on the bus for component cards.

5.2.2.1 Use buses that provide the necessary performance economically and are compatible with the board level components that are needed to meet requirements. For buses that provide slots for component cards, use standard buses that are supported by multiple vendors providing compatible component cards.

5.2.3 Main Memory—Main memory is the storage warehouse of the computer where data and programs are stored for efficient processing. In the context of this section, main memory refers to cache and RAM. The main factor to consider in acquisition of a computer system is the quantity (in megabytes) of RAM. Other considerations are access speed, mounting design, and parity. Computer systems with too little memory run slowly, won’t load, and crash often. Mounting designs today generally provide for easily upgradeable Memory Modules. SDRAM (Synchronous Dynamic Random Access Memory) has long been a standard for memory, but more advanced designs such as DDR (Double Data Rate) and Rambus memory offer better speed and throughput and are rapidly gaining wide acceptance. Older architecture memory designs are generally slower and less efficient and should be avoided to the extent possible.

5.2.3.1 Cache is usually hard wired to the motherboard and has a faster access time than RAM. Computer system caches of 512 KB or larger are generally satisfactory.

5.2.3.2 RAM can often be on a separate memory board and is used to store the OS, applications that are running, and data files. The amount of RAM needed for a computer system can vary with the environment and the OS. Servers generally need about an order of magnitude more RAM than personal workstations. For personal workstations with a 16/32 bit operating system, 64 MB or more of RAM is recommended; for workstations with 32/64 bit operating systems, 128 MB or more is recommended. For servers, use the Network Operating System (NOS) guidelines based on the environment. The three major factors used to determine the amount of RAM for a server are number of user connections, number of processes running, and amount of hard drive space.

5.2.4 Input/Output (I/O) Interfaces—I/O interfaces allow the computing resource to move data between the “outside world” and the CPU and main memory. Operations like loading a program or file from a floppy or CD, sending and receiving information over the LAN or WAN, or sending a document to the printer to get a hardcopy use I/O interfaces. Quite often the information is sent to or received from a peripheral, which is discussed in the next section.
NOTE 1—Extended Data Out (EDO) DRAM was long a standard for mass-market memory, but Synchronous DRAM (SDRAM) is now the standard for currently installed machines. SDRAM is a memory architecture that incorporates many improvements over traditional DRAM technologies. SDRAM is a new technology that runs at the same clock speed as the microprocessor. The clock on the memory chip is coordinated with the clock of the CPU, so the timing of both the memory and the CPU are “in synch.” This reduces or eliminates wait states, and makes SDRAM significantly more efficient than Fast Page Mode (FPM) or even Extended Data Out (EDO) memory.

NOTE 2—Even more speed and throughput improvements are being realized with Double Data Rate (DDR) and Rambus Memory; selection of a memory architecture will need to be made according to a careful consideration of cost (particularly over the anticipated service life of a system) and performance considerations.

TABLE 4 Recommended Memory (RAM) Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Dynamic Random Access Memory (DRAM)</td>
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<tr>
<td>Extended Data Output Dynamic Random Access Memory (EDO DRAM)</td>
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</tr>
<tr>
<td>Synchronous Dynamic Random Access Memory (SDRAM)</td>
<td></td>
</tr>
<tr>
<td>Double Data Rate Memory (DDR)</td>
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</tr>
<tr>
<td>Rambus Memory</td>
<td></td>
</tr>
</tbody>
</table>

5.2.4.1 Use I/O interfaces that use open access standards, support open device connections, and are platform independent.

5.2.5 Peripherals—Peripherals provide data access, input, storage, and connectivity for a computing resource. The number of peripherals available on the commercial market continues to explode, generally driven by processor speeds, memory/storage capacities, and I/O speeds. Although there are many different types of peripherals, such as printers, facsimiles, modems, scanners, video cameras, microphones, speakers, and so forth, the main issue in specifying/procuring these items is the compatibility of their I/O interfaces with the computer (see 5.2.4) and application software. Apart from these compatibility issues, the major considerations for acquiring peripherals are cost and performance (which can include both speed and quality). A major category of peripherals is static storage devices. As distinguished from main memory (covered in 5.2.3), static storage devices retain data when the power is off. The remainder of this section will discuss storage devices. Use peripherals that support standard I/O interfaces and are platform independent.

5.2.5.1 Storage Device Standards—Storage refers to the capability to store information outside the central processor. For most computers, the predominant technology for storage has been magnetic disk and will remain so for the next few years.

TABLE 5 Recommended I/O Interface Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Notes</th>
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<tbody>
<tr>
<td>SCSI-2</td>
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<tr>
<td>USB</td>
<td></td>
</tr>
<tr>
<td>IEEE 1394</td>
<td></td>
</tr>
<tr>
<td>FC-PH/FC-AL</td>
<td></td>
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<tr>
<td>XIO</td>
<td></td>
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<tr>
<td>ESCON</td>
<td></td>
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<tr>
<td>Serial</td>
<td></td>
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<tr>
<td>IPI</td>
<td></td>
</tr>
<tr>
<td>Parallel</td>
<td></td>
</tr>
<tr>
<td>PC Card</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1—Fibre Channel (FC-PH) is emerging as a host-level interface standard for delivery of high I/O data transfers. FC-PH provides connections for workstation clustering, storage clustering and network-based storage concepts, parallel processing, load leveling, host-to-host or server-to-server communications, host- or server-to-mass storage communications, bulk data transfer, and multimedia. FC-PH is also being used as a system bus at the CPU and memory level as well as a way to cluster multiple systems similar to Non-Uniform Memory Access (NUMA). NUMA describes an architectural approach to clustering multiple systems such that distributed memory appears to the operating system as shared memory. This architectural approach allows a benefit to the user of a shared memory programming model with the scalability of a massively parallel processor’s (MPPs) distributed memory model. FC-PH currently provides up to 1.062 GigaBits Per Second (Gbps) bandwidth using optical fiber.

NOTE 2—FC-PH-based storage subsystems will be supported on mainframes; therefore, the Enterprise Systems Connection or ESCON-based systems will be phased out.

NOTE 3—The Upper Layer Protocol (ULP) over FC-PH from the mainframe will initially deploy as SCSI-2 or SCSI-3 and migrate quickly to Intelligent Peripheral Interface (IPI). IPI will be deployed on large servers before it will be deployed on mainframes. Note that IPI is a protocol only; SCSI is both a protocol and an interface. FC-PH is an interface that can support various ULPs.

NOTE 4—For servers and higher end personal workstations, SCSI is the predominant host-level interface for current disk and peripheral devices. As the demand for higher data transfer rates and expanded connectivity requirements increase, SCSI-2 and SCSI-3 over FC-PH in a PCI form factor will be the appropriate long-term direction.

NOTE 5—Enhanced IDE is the predominant peripheral interface for lower end personal workstations. SCSI is the current interface of choice for high-speed devices, such as high-capacity disk and tape drives and is the appropriate long-term direction for both the commodity level and high capacity devices.

NOTE 6—Personal Computer Memory Card International Association (PCMCIA) announced that PCMCIA cards are now referred to as PC Cards. The PC Card Standard defines a 68-pin interface between the peripheral card and the PC Card “socket” into which it gets inserted. It also defines three standard PC Card sizes, Type I, Type II and Type III. All PC Cards measure the same length and width, roughly the size of a credit card. Where they differ is in their thickness. Type I, the smallest form factor, often used for memory cards, measures 3.3 mm in thickness. Type II, available for those peripherals requiring taller component such as LAN cards and modems, measures 5 mm thick. Type III is the tallest form factor and measures 10.5 mm thick. Type III PC cards can support small rotating disks and other tall components.

NOTE 7—As mentioned under “Bus” (see 1.1.2), CardBus is a new standard introduced as an addendum to the PCMCIA PC Card standard. CardBus is a 32-bit bus-mastering card operating at 33 Mhz transferring data at up to 132 MBytes per second. (The 16-bit PC Card bus data rate is 20 MBytes per second.) Like PC Cards, CardBus uses the 68-pin interface but operates at 3.3 volts versus the 5 volts used by PC Cards. CardBus slots are backward compatible with PC Cards. Card sockets can support PC Cards only or CardBus cards only, but not a mixture of the two.

NOTE 8—Serial I/O refers to standard serial interfaces such as RS 232, 422, 423, and 449.

NOTE 9—Parallel I/O refers to standard parallel interfaces such as micro-Centronix.

NOTE 10—XIO is an emerging I/O solution based on Specialist’s S1 controller, and incorporating the high performance I/O processor and communication technology introduced in the RIO range. XIO is ideal for the 16-32 user system where sustaining high performance is essential.

NOTE 11—IEEE 1394, also known as “Firewire,” is a high speed serial I/O that supports data rates up to 400Mbps.
5.2.5.2 RAID Technology—Redundant Array of Independent Disks (RAID) technology protects from data loss by providing a level of redundancy immediately within an array. The array contains removable disk drive modules that are automatically rebuilt in the event of a device failure without causing the system to shut down. When RAID levels other than 0 are used, no downtime is required to replace a failed disk drive. Data is continuously available while reconstruction of the failed disk occurs in the background. Much of the benefit of RAID technology lies in its capability to off-load storage management overhead from the host system. To realize this benefit, RAID developers endow their array controllers with significant levels of intelligence. For instance, Adaptive RAID supports multiple RAID levels based on workload characteristics. Choose the RAID level based on your specific need.

5.3 System Configurations—The hardware component technologies mentioned in 5.2 can be configured in many different ways to accomplish different tasks and meet different requirements. This section examines some of the common configurations (Personal Workstations, Servers and Embedded Computers) with guidance on what component technologies to use for each configuration.

5.3.1 Personal Workstation—Personal Workstations (PW) are devices that contain at least one CPU (sometimes several) and provide a user interface, typically a GUI, as well as personal productivity tools, local data storage, and a flexible method for accessing and manipulating data. These PWs are commonly known as Personal Computers or PC’s, desktop computers, portables (laptops or notebooks), or workstations and use one of several bus architectures. Low-end PWs are used primarily to support the general office workplace. More powerful PWs are predominantly used in high-end computer applications such as Computer-Aided Design/Computer-Aided Manufacturing/Computer-Aided Engineering (CAD/CAM/CAE), application development, multimedia, and decision support data analysis presentation.

5.3.1.1 Also included in PWs are handheld computers—Personal Digital Assistants (PDAs), also referred to as Personal Information Managers (PIMs). Handhelds are computer systems that fit in a person’s hand and are extremely portable. Handheld systems also tend to have two types of input methods: pen or keyboard. The pen input can be used as digital ink, a mouse, or for handwriting recognition.

5.3.1.2 Combine components that provide flexible, scalable, and easy-to-use personal workstations that support the Client/Server model of computing, data access, and multimedia. Allow for an external communication device such as a modem or network interface card.

5.3.1.3 Table 9 provides a quick summary of the nominal specifications for Personal Workstation implementation.

5.3.2 Servers—Servers are computing resources that can be configured to support groups from small teams (work group

### TABLE 6 Storage Device Media

<table>
<thead>
<tr>
<th>Storage Device Media</th>
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<tbody>
<tr>
<td>3.5 in. magnetic disk</td>
</tr>
<tr>
<td>3.5 in. floppy disk</td>
</tr>
<tr>
<td>5.25 in. WORM</td>
</tr>
<tr>
<td>5.25 in. MO</td>
</tr>
<tr>
<td>ISO 13346</td>
</tr>
<tr>
<td>CD-ROM</td>
</tr>
<tr>
<td>Flash Memory Removable Devices</td>
</tr>
<tr>
<td>Smart cards</td>
</tr>
<tr>
<td>DVD</td>
</tr>
<tr>
<td>½-in. helical tape</td>
</tr>
<tr>
<td>4 mm DAT</td>
</tr>
<tr>
<td>DLT Tape</td>
</tr>
<tr>
<td>3490E cartridge tape</td>
</tr>
</tbody>
</table>

Note 1—8-mm helical tape is appropriate for backup and archive use; however, it is slow and unreliable for near-line storage solutions where frequent access is required. 4mm DAT offers a faster, more reliable solution to high-capacity and high-access applications.

Note 2—½-in. helical tape offers higher storage capacity than 4 mm or 8 mm; however, it is expensive, proprietary, and only Storage Technology supports it.

Note 3—3490E square cartridge ½-in. tape is predominantly a mainframe technology for off-line data storage.

Note 4—Higher capacity tape applies capacity multipliers of $2^X$ to $4^X$ to current technology. Gains are achieved through increased density factors as well as media length (number of media ft per unit).

Note 5—Flash Memory Storage devices are finding wide acceptance in Asia. They can hold as much as 128 MB of data in a keychain form factor that plugs into an available USB port.

Note 6—Smart cards are being used in Europe and Asia. Smart cards will be used predominantly as an intelligent storage media for providing services to individuals.

Note 7—the Digital Video Disk (DVD, also known as Digital Versatile Disk) allows for dual-sided as well as dual-layered implementations that will increase CD-ROM capacities significantly. In addition, transfer rates may improve to as high as 16 Mega Bits Per Second (Mbps).
servers) to entire ships (campus servers). Work group servers provide support, such as directory, file, print, and authentication services, in a LAN environment. Campus servers may augment and, for many new applications, replace traditional mainframes. Selecting systems that address and support features and services of both systems management and reliability, availability, and serviceability is important. Campus servers often implement RAID storage technology to provide services with high reliability and availability (see 5.2.5.2).

5.3.2.1 There are different types of servers, performing more specific functions. Some of these server types include: database servers, multimedia servers, data push server, applications server, optical disk servers, and mail servers. A brief description of these servers follows:

1. **Database Servers**—Large databases make extensive use of disk space and processor power and typically require their own dedicated database server hardware. Increasingly these database servers have more than one CPU and more than one network interface channel to keep up with the demands placed upon them by large numbers of simultaneous users.

2. **Multimedia Servers**—If an installation has a large archive of audio or video data, or if it intends to distribute audio or video data in real-time, it will require a multimedia data server. Archives of audio and video data require huge amounts of disk space. Moving this data over the network (typically through streaming audio or video services and protocols) is also resource intensive. Both requirements typically require the dedicated use of a multimedia server.

3. **Data Push Servers**—If an installation implements a data push mechanism for distributing information to internal and/or external desktops, it will have to host that push function on a data push server. Depending on the number and volume of channels being pushed, the data push server software may reside on hardware that is also performing other server functionality (typically the web server).

4. **Application Servers**—One option for centralizing system management and reducing total cost of ownership in a network environment is to run the actual application programs on a few high-powered application servers rather than on the desktop clients. This is a common approach in UNIX-based computing environments through the use of the X Windows graphical interface to open display and control windows on one system for an application running on another system. A new variation of this approach brings current Microsoft Windows applications to systems that are under-powered (old 286 or 386 CPU PCs) or that are not running the 16/32 bit based Windows operating system (UNIX workstations, Java Network Computers). This is made possible by running the applications on shared Windows NT/2000 application servers and just sending the user interface over the network to the user’s local system.

5. **Optical Disk Servers**—With the huge amounts of reference data available on CD ROM and the increasing availability of CD ROM writers for organizations to use to create their own archival data storage on CD ROM, there is a growing need to have multiple CD ROM disks online at once. A new class of hardware, the CD ROM Server, is a stand-alone network device that includes a large number of CD ROM drives which can be made available as shared disks to all users on a network.

6. **Mail Servers**—In an organization that has a number of networked PW clients, mail servers provide store and forward functions for electronic messages. These servers receive, store, and distribute electronic messages and require a large amount of storage, proportional to the number of e-mail accounts they carry. They also require numerous network connections and modem connections to receive and distribute messages from/to users and other organizations.

5.3.2.2 Evaluate servers for their interoperability, portability, reliability, availability, serviceability, and scalability. The capability to easily upgrade processor performance or to add additional processors, disk storage, and communications supports extend the life of the platform and enhances the return on investment. Use hardware components that are standards-based, primarily those that are compatible with interface bus standards. Select scalable servers that can increase performance by adding components and by supporting standards-based network protocols. Through the use of a multiprocessing architecture, hardware should be scalable and should enable parallel processing.

5.3.3 **Embedded Computers**—When readily available computers do not meet the requirements, components must be integrated to form a system. This often involves a design of board level components to perform the necessary functions. The major design consideration is the selection of a back plane

---

**TABLE 8** Recommended Personal Workstation (Desktop) Hardware Configuration Guidance

<table>
<thead>
<tr>
<th>CPU</th>
<th>Bus</th>
<th>Memory</th>
<th>I/O</th>
<th>Peripherals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium/Celeron</td>
<td>PCI</td>
<td>RAM ≥ 128MB</td>
<td>E/IDE</td>
<td>HD &gt; 10GB</td>
</tr>
<tr>
<td>K6/ Athlon/Duron</td>
<td>EISA</td>
<td>Cache ≥ 512KB</td>
<td>SCSI-2,3</td>
<td>3.5-in. floppy</td>
</tr>
<tr>
<td>C3/Cyrix</td>
<td>USB</td>
<td>CD-ROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power/PC</td>
<td>IEEE-1394</td>
<td>DVD</td>
<td>PC Card or Cardbus</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**—EISA bus should be used only to accommodate legacy systems.

**TABLE 9** Personal Workstation Configuration Summary

<table>
<thead>
<tr>
<th>Processor</th>
<th>Personal Workstation also used as a Server</th>
<th>Desktop</th>
<th>Laptop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium/Celeron</td>
<td>Pentium/Celeron</td>
<td>Pentium/Celeron</td>
<td></td>
</tr>
<tr>
<td>K6/Athlon/Duron</td>
<td>K6/Athlon/Duron</td>
<td>K6/Athlon/Duron</td>
<td></td>
</tr>
<tr>
<td>Duron C3/</td>
<td>C3/Cyrix</td>
<td>C3/Cyrix</td>
<td></td>
</tr>
<tr>
<td>Cyrix/PowerPC</td>
<td>PowerPC</td>
<td>PowerPC</td>
<td></td>
</tr>
<tr>
<td>System Bus</td>
<td>PCI</td>
<td>PCI</td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>256 MB SDRAM</td>
<td>256 MB SDRAM</td>
<td></td>
</tr>
<tr>
<td>Input/Output</td>
<td>E/IDE</td>
<td>E/IDE</td>
<td></td>
</tr>
<tr>
<td>SCSI-3</td>
<td>PC Card X2</td>
<td>PC Card X2</td>
<td></td>
</tr>
<tr>
<td>PC Card X2</td>
<td>Serial</td>
<td>Serial</td>
<td></td>
</tr>
<tr>
<td>Parallel</td>
<td>USB</td>
<td>USB</td>
<td></td>
</tr>
<tr>
<td>USB</td>
<td>IEEE 1394</td>
<td>Modem</td>
<td></td>
</tr>
<tr>
<td>IEEE 1394</td>
<td>Modem</td>
<td>NIC</td>
<td></td>
</tr>
<tr>
<td>Dual Network</td>
<td>NIC</td>
<td>(Modem and NIC can be on a PC Card)</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Card (NIC)</td>
<td>be on a PC Card</td>
<td></td>
</tr>
<tr>
<td>3.5-in. floppy</td>
<td>3.5-in. Floppy</td>
<td>3.5-in. Floppy</td>
<td></td>
</tr>
<tr>
<td>CD-ROM</td>
<td>10 GB HDD</td>
<td>10 GB HDD</td>
<td></td>
</tr>
<tr>
<td>4-mm DAT</td>
<td>40 GB HDD</td>
<td>40 GB HDD</td>
<td></td>
</tr>
<tr>
<td>Operating System</td>
<td>64 bit</td>
<td>32 bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16/32 bit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
bus that will allow all of the components to communicate with each other. This decision can impact dramatically the cost, both in the development and the logistics support of the system. Considerations in determining the bus include availability of components and existing systems bus architectures (to reduce the logistics support costs). Commercially available components should be considered first before custom designing and building the components. When designing embedded computer systems, use industry standard buses and standard components to the maximum extent possible.

6. Cable Plant

6.1 The cable plant includes copper cable and fiber optic cable. Fiber optic cable is the solid media preferred for its current high-capacity (100’s of Mbps), future bandwidth potential (Gbps to Tbps), reliability, reduced susceptibility to Electromagnetic Interference (EMI), and security. (Although fiber cannot be made completely secure without encryption or proper physical protection, it cannot be “tapped” without physical manipulation.)

6.2 Fiber optic cable is required to support voice and high-speed data. Fiber optic cable is recommended in other areas where feasible. If cost limits its use, then fiber optic cable should be run at least in the backbone of the network and to areas, which are already wired. However, it is recognized when linking distant, or otherwise limited-access areas, that can be easily, and inexpensively, rewired with fiber when appropriate. If copper is used, select only properly terminated and tested Category 5 (“Cat 5”) cable for cable from the telecommunications closet to the desktop. (Unshielded Twisted Pair (UTP) Cat 5 is the copper standard for data rates up to 155 Mbps.) Thin-wire coax, thick-wire coax, RS-232/422, Category 3 and “telephone” wire should be avoided—the minor cost savings is not usually justifiable because of limited data rates and degraded interoperability. (Allowable exceptions are recognized when linking distant, or otherwise limited-access areas, which are already wired.)

6.4 Definitions:

6.4.1 Trunk Cable—A trunk cable is a cable that connects two main interconnection boxes or patch panels. It is used to provide connectivity between the service areas of the cable plant.

6.4.2 Local Cable—A local cable is a cable that connects a main interconnection box or patch panel to user system equipment or a local breakout box.

6.4.3 System Specific Cable—A system specific cable directly connects two pieces of user system equipment, independent of the cable plant. A system specific cable is typically used to connect equipment within the same service area of the cable plant.

6.4.4 Drop Cable—A drop cable is a system specific cable between a ready movable piece of user system equipment, such as a PC or printer, and the local breakout box in the area. A drop cable is not considered to be part of the cable plant.

6.5 Fiber Optic Cable—Fiber optic cable is the preferred media for all network applications due to its growth potential. (In shipboard and other high Electromagnetic Interference (EMI) environments, fiber optic cable is critical in eliminating the effects of noise.) The backbone network must use fiber optic cabling, as part of the Fiber Optic Cable Plant (FOCP)—twisted pair (shielded or unshielded) or coaxial cable should not be used. Where possible, multimode graded index fiber with a 62.5-micrometre (µm) core/125 µm cladding should be used. Due to the low relative marginal cost, single-mode fiber (8 µm core/125 µm cladding) should be provided in at least the backbone FOCP and preferably to major junction points.

6.5.1 Multimode fiber (62.5 µm) is easier to terminate and test, especially in the field. However, there are distance and bandwidth limitations that cannot be overcome and single-mode fiber must be used. (Multimode fiber can support rates of up to 155 Megabits per second (Mbps) at distances up to 2 kilometres (km). It can only support 622 Mbps for hundreds of feet. Single-mode fiber (8 µm), however, can easily support units of Gigabits per second (Gbps) at up to 30 kms. Further, it can support multiple wavelengths, each operating at units of Gbps. Thus today’s single-mode fiber can support tens of Gbps.

### TABLE 10 Server Hardware Configuration Guidance

<table>
<thead>
<tr>
<th>CPU</th>
<th>Bus</th>
<th>Memory</th>
<th>I/O</th>
<th>Peripherals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium</td>
<td>PCI</td>
<td>RAM ≥ 512MB</td>
<td>SCSI-2, 3</td>
<td>Hard Drive</td>
</tr>
<tr>
<td>MIPS</td>
<td>VME/VXI</td>
<td>Cache ≥ 2MB</td>
<td>FC-PH</td>
<td>CD-ROM/CD/DVD</td>
</tr>
<tr>
<td>Alpha</td>
<td>CardBus</td>
<td>PC Card or RAID 1,3,4,5,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PowerPC</td>
<td>SBUS</td>
<td>CardBus</td>
<td>4-mm DAT</td>
<td></td>
</tr>
<tr>
<td>RISC</td>
<td>EISA</td>
<td>IP</td>
<td>DLT</td>
<td></td>
</tr>
<tr>
<td>UltraSparc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 11 Embedded Computer Systems Hardware Configuration Guidance

<table>
<thead>
<tr>
<th>CPU/Cel/eron</th>
<th>Bus</th>
<th>Memory</th>
<th>I/O</th>
<th>Peripherals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium</td>
<td>VXI</td>
<td>TBD</td>
<td>SCSI-2, 3</td>
<td>Hard Drive</td>
</tr>
<tr>
<td>Power PC</td>
<td>VME</td>
<td>FC-PH</td>
<td>3.5-in. floppy</td>
<td></td>
</tr>
<tr>
<td>KB/Alpha</td>
<td>PCI</td>
<td>IPI</td>
<td>CD-ROM</td>
<td></td>
</tr>
<tr>
<td>MIPS</td>
<td>GPIB/HP-IB</td>
<td>ESCON</td>
<td>DVD</td>
<td></td>
</tr>
<tr>
<td>SPARC</td>
<td>EISA</td>
<td>EIDE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpha</td>
<td>SBUS</td>
<td>Serial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cruseo</td>
<td>CardBus</td>
<td>Parallel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PC Card or CardBus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(A) Varies widely based upon system requirements.

Note 1—Although VME bus is more popular and offers a wider variety of vendor products, VXI bus offers a greater degree of standardization and therefore a greater degree of interoperability among vendors’ products. These are the buses of choice for embedded systems.

Note 2—As the popularity of PCI bus rises and the number of available products increases, PCI becomes a more desirable architecture for embedded systems.
for tens of kilometres. Laboratory tests have shown this limit to be at least 2 orders of magnitude higher, namely Terabits per second (Tbps).

6.5.2 Unshielded Twisted Pair (UTP)—Category 5 UTP cable may be used only for the cabling between the appliance and the network edge device or between the workstation and other network equipment under certain conditions. Shielded Twisted Pair (STP) cable should not be used. The following factors should be taken into consideration when using Category 5 UTP cable:

6.5.2.1 Mission criticality of the application (The UTP copper cable may exhibit a lower availability than fiber due to EMI problems.)

6.5.2.2 Bandwidth or signaling rate (UTP may be used for short runs of 100BaseT, but should not be used at higher data rates or for long runs.)

6.5.2.3 Security level (UTP is easy to tap if not run in conduit.)

6.5.2.4 Length of cable run (UTP should be limited to intra-compartment runs.)

6.5.2.5 Installation factors (UTP requires exceptional care during installation, and should be thoroughly tested.)

6.5.2.6 Environmental Factors—EMI (UTP is subject to interference from radar and nearby high-powered equipment.)

6.5.3 In ship and marine environments, UTP cable should meet general flammability, smoke, acid gas generation, halogen content, and toxicity index requirements. Further, UTP should be limited in critical systems to due to EMI, shock, and vibrations (RJ-45 plastic connectors for UTP are not designed to withstand significant shock loads and may crack or disconnect under long-term vibration conditions).

6.5.4 Legacy Copper-Media Networks—For installations with copper-based legacy systems, it is recommended that those systems be selectively upgraded to fully integrate users of the backbone network based on capability requirements and funding availability. In ship and marine environments where upgrade funding availability or system requirements cannot support the decision to upgrade the system, connectivity to the ship’s backbone network can be accomplished at either the backbone or workgroup switch, providing that those devices can support the legacy network protocols. In such a configuration, the backbone network switch acts as a gateway between the legacy system and the rest of the backbone. If some limited funding for system upgrade is available, and such upgrades suit the needs of the ship, a lower cost interim upgrade would be to replace the legacy copper links with fiber optic links, and integrate those links into the ship’s FOCP. This interim physical integration will simplify the further upgrade from a separate legacy system to an integrated network application.

6.5 Patch Panels, Interconnection Boxes, and Connectors:

6.5.1 FOCP Interconnection Boxes—FOCP interconnection boxes and patch panels should hold a minimum of 48 connector pairs. Interconnection boxes should be sized to accommodate all of the fibers (allocated, spare, and growth) that enter the box.

6.5.2 Local Breakout Boxes—Local breakout boxes may be used to provide additional flexibility in locating workstations or easily moved equipment. The interconnection box should completely enclose the fiber terminations. Local breakout boxes should not be used as a substitute for rack-mounted patch panels for the interconnection of rack-mounted equipment.

6.6.3 Location of Tx-Rx Pairs and Optical Crossover—In FOCP Interconnection Boxes, local breakout boxes, and in rack-mounted patch panels, the pair of ST connectors associated with one full-duplex optical circuit should be located in a vertical line, one above the other, with the transmit (Tx) connector above the receive (Rx) connector. In a complete optical link, there must be one (or an odd number of) crossover(s) in order to connect the optical transmitter at one end to the optical receiver at the other end, and vice versa.

6.7 Connectors

6.7.1 Fiber Optic Cable:

6.7.1.1 ST-type—ST-type connectors were, until recently, the standard for all multimode connections. In commercial applications, SC is rapidly becoming the standard. It is becoming hard to find host network interface cards with ST connectors.

6.7.1.2 SC-type—SC-type connectors are becoming the industry standard for both host network interface cards and backbone connections. While this is acceptable for multi-mode fiber, it has debatable merit for single-mode fiber. (Pros: more common connector, easier to insert/remove; Cons: can more easily confuse multi-mode with single-mode fiber, if single-mode transmitter accidentally plugged into multi-mode receiver, the receiver could be permanently damaged.)

6.7.1.3 FCPC-type—FCPC-type connectors are the standard for single-mode fiber. Many equipment vendors, however, are beginning to use SC-type connectors. Because the risk of accidentally switching multi-mode and single-mode connections exists when the same connector is used for both, it is recommended that FCPC-type be used for single-mode fiber (see discussion in the previous paragraph).

6.7.1.4 MIC-type—MIC-type connectors are not recommended for use within the backbone network. However, if MIC-type connectors are the only available option, it is recommended that a MIC-ST jumper cable be fabricated to allow the MIC connector at the equipment interface, but with an ST connector for connection to the FOCP or rack-mounted patch panel. MIC connectors should not be used within FOCP interconnection boxes.

6.7.1.5 Heavy-Duty Multiple Terminus—Heavy-duty multiple terminus connectors are recommended for equipment interfaces that require a rugged interface that is easily disconnected and reconnected.

6.7.1.6 Mechanical Splice—Mechanical splices are recommended only for those applications requiring higher optical performance than is available with ST-type connectors. Mechanical splices may be used in interconnection boxes, and may also be used inside rack-mounted patch panels where needed for higher optical performance.

6.7.2 Copper Cable:

6.7.2.1 RJ-45 Connectors—Category 5 cable specifications limit the connector type to RJ-45. However there are a number of pin-out standards from which to choose. Because ISDN also specifies the use of RJ-45, the ISDN pin-out specification will
be used: ANSI/EIA/TIA-568-1991 Standard, Commercial Building Telecommunications Wiring. This variant is designated EIA/TIA T568A (also called ISDN, previously called EIA).

6.7.3 Ship and Marine Environment—In ship and marine environments, ST-type connectors are recommended for all light-duty multi-mode fiber applications. ST-type connectors may be used as the interface to equipment if sufficient cable strain-relief and protection are provided. Failure to provide sufficient strain relief and protection will result in connector breakage or failure.

6.7.3.1 Until such time as SC-type connectors are evaluated against shock, vibration, and wear, they are not recommended for use within the backbone network. However, if SC-type connectors are the only available option associated with the network equipment, it is recommended that an SC-ST jumper cable be fabricated to allow the SC connector at the equipment interface with an ST connector for connection to the FOCP or the rack-mounted patch panel. SC connectors should not be used within FOCP interconnection boxes.

6.8 Topology, Security, and Integrated Cabling:

6.8.1 Basic Topology—The recommended physical topology is a mesh, as opposed to a ring or star configuration. If a logical ring or star topology is required for near-term cost reasons, the physical mesh cable plant infrastructure can be configured to provide the required logical topology. The mesh physical architecture will support the future expansion or upgrade to a full mesh logical topology.

6.8.2 Network Node Locations—Node locations should be selected based on the concentrations of current and planned network users. Nodes should be located in secure areas, to preclude unauthorized access to the equipment. Nodes should also be located in temperature controlled compartments, to optimize equipment reliability. Note that there is a trade-off between the number of nodes and the total quantity of local cable required to connect users. These two parameters should be considered in conjunction with the system requirements for survivability when determining the appropriate number of nodes.

6.8.2.1 Users should be connected to nodes within the same fire zone for survivability. Also, the number of nodes installed should be selected to provide maximum coverage of the ship’s fire zones, while minimizing the total network cost.

6.8.3 Patch Panel and Interconnection Box Locations—Main interconnection boxes or patch panels should be collocated with the network nodes. For maximum installation and connection flexibility, it is recommended that the patch panels be installed in the same rack as the network node equipment. These rack-mounted patch panels can also be used to provide a convenient means of interconnecting equipment within the same rack, and to provide a simplified disconnect point in the event that racks must be moved.

6.8.3.1 For racks containing connection-intensive network devices, the use of a rack-mounted patch panel should be considered to serve as the interconnection box for that zone.

6.8.4 Trunk Cable Routing—In general, trunk cables should be routed along diverse physical paths to ensure a survivable FOCP. The degree of redundant/fail-over equipment is cost-driven but with a proper FOCP mesh, outages can be quickly restored using alternate cable paths.

6.8.4.1 Trunk cables should be routed to provide survivable signal paths between interconnection boxes. In general, each trunk cable should have an identical redundant cable following a separate route between the two interconnection boxes. In addition, the cables should be routed on opposite sides of the ship, with at least two decks separating them vertically.

6.8.5 Local Cable Distribution—If a single user has multiple local cables for redundancy or survivability, those local cables should be routed to two different interconnection boxes, and should be separated within 60 ft of the equipment.

6.8.6 Network Fiber Allocations:

6.8.6.1 Inter-node—Fibers should be allocated for all inter-node connections. The level of inter-node connectivity should be determined based on current technical requirements, future projections of requirements, and overall program cost constraints. In general, it is desirable to include sufficient fiber in the FOCP to allow for full inter-node connectivity in a mesh topology. Any interim logical configurations, such as rings or stars, should also be considered when determining fiber requirements.

6.8.6.2 Redundancy—Redundant fibers in survivable separated trunk cables should be provided for each active and spare user system fiber. This is particularly critical in ship and marine environments.

6.8.6.3 Spares—Spare fibers should be provided on a 100 % basis; that is, each actively used fiber should have an assigned spare. This is particularly critical in ship and marine environments.

7. Wireless Networking

7.1 The establishment of standards such as IEEE 802.11 has created the ability of computers to communicate via network protocols without physical wiring. Commonly known as wireless Local Area Networks, this innovation provides practical interconnectivity without the investment or labor required to establish physical media.

7.2 Wireless networks operate on a range of frequencies and bandwidths, with newer systems functioning at 2.4 GHz frequencies and with a bandwidth of approximately 11 Mbs. These networks operate at a range of up to 90 m indoors, and out of doors can operate up to 300 m. Actual communication methods may vary, however, and care must be exercised to ensure that equipment from various vendors is compatible.

7.3 Workstations equipped with compatible wireless networking cards can operate in a peer-to-peer fashion, but in a larger installation a more reasonable design would be to establish distinct Wireless Access Point (WAP) devices that connect directly to the cable plant and act as gateways to the physically wired network and attached servers. In this scenario, wireless workstations may be moved from location to location within a ship and connect to the network wherever a WAP is established. Laptops and PDAs are particularly well suited to support WAP installations, due to their inherent mobility.

7.4 The ability of a wireless-configured device to easily connect to another wireless device or WAP also highlights one of the disadvantages of wireless networks. Security of operating data, services and systems can be seriously compromised in
8. Ship and Marine Facility Requirements

8.1 Racks—Ship and marine networking equipment should never be installed by setting them upon desks, tables, filing cabinets, etc. Small equipment can be bulkhead-mounted or hung from the overhead; however, the preferable technique for ship and marine installation of standard information processing equipment is in racks.

8.1.1 Suitable racks can be obtained from a number of vendors. However, heavy duty, industrial grade or ruggedized racks should be used, not lightweight racks intended for shore-based office environments. Standard rack widths are 19 in. and 24 in. Nearly all typical networking equipment is designed to fit into 19-in. wide racks. (Note that these are mounting widths; the overall external width of a 19-in. rack is about 24 in., and the outside width of a 24-in. rack is about 30 in.)

8.1.2 Standard 19-in. racks come in several depths, typically 17 in., 24 in., 29 in., and 36 in.. When deciding on the depth of a rack, remember to allow enough depth for recessing equipment that have front-access cabling, and to allow air exhaust space for equipment with rear-facing fans. Many pieces of networking equipment have modular assemblies that are removed from the front, and the cables attach to these assemblies from the front. This requires that the unit be recessed at least 4 in. to allow a reasonable cable bending radius. (For units that have rear-accessible modules, it is often desirable to mount them in backwards for easier access to removable modules.)

8.1.3 If there is sufficient space in the compartment to mount the racks away from the bulkhead for both front and rear access, a sufficiently deep rack will permit electronics units and fiber patch panels to be placed back-to-back at the same vertical level within the rack.

8.1.4 Consider cable entry when ordering racks. If the rack is to be located on a raised false deck, then the cabling can enter from the bottom. Otherwise the cable should enter the rack from the lower half of the rear panel. For all cable entrances, a minimum of three in. of slack should be provided to allow for movement of the rack under shock and vibration. There should also be a minimum length of 18 in. between the last cable support and the cable’s entrance to the equipment.

8.1.5 Racks should be ordered with removable, but lockable, side, front and rear panels for maximum equipment accessibility. Note that the location of louvers in rack panels depends upon the cooling method that is used (see below).

8.1.6 The location of equipment within racks is a trade-off among the often-conflicting parameters of accessibility, weight, and cooling. Heavy equipment should be located low in the rack for stability and ease of removing. Equipment that requires reading of displays, LEDs, or patching should be located at eye level. Heat-dissipation equipment should be located near the air exhaust, not near the cold air inlet, to avoid pre-heating the air flowing over the rest of the equipment.

8.1.7 Heavy equipment should be mounted using front-to-rear angle brackets or slide trays to simplify installation and removal, and to avoid the need to carry the weight of the equipment on the front panel screws.

8.1.8 Rack Cooling—Racks that contain equipment whose total power dissipation is more than 100 W should be provided with rack-mounted blowers or fans to augment any cooling that might be provided by fans inside the equipment.

8.1.8.1 The ft³/min (CFM) rating of the rack blower/fans can be estimated from the following equation:

\[
CFM = 4P/T
\]

where:

\[
CFM = \text{airflow, ft}^3/\text{min},
\]

\[
P = \text{total rack power dissipation, W, and}
\]

\[
T = \text{temperature rise (inlet to outlet), } ^\circ\text{F.}
\]

For example, a rack with 1000 W of electronics will need a 400-CFM blower to limit the temperature rise to 10°F.

8.1.8.2 Since heated air tends to rise, the airflow from fans or blowers should be bottom-to-top. This means placing a blower at the bottom of the rack, or an exhaust fan at the top of the rack. In either case, a washable air filter should be placed at the air entry point. Note that the blower, as opposed to the exhaust fan, has the added advantage of putting a positive pressure within the rack to keep out dust and dirt from unfiltered air entry.

8.1.8.3 If a blower is placed at the bottom of the rack, then the rear or side panels, or both, should have louvers near the top for exhaust air to exit. Do not use fully louvered panels that would short circuit the air flow. If exhaust fans are used, then the doors and panels should have no louvers; the cold air enters from the air filter near the bottom and the warm air exits via the top-mounted exhaust fan.

8.1.9 Shock Isolation—Ship and marine equipment racks should not be hard-mounted to deck foundations, but should be shock isolated via coil springs or other acceptable isolation mechanisms. Tall racks (over 1.5 m tall) should also have shock-isolated anti-sway mounting from the top of the rack to the bulkhead or to the overhead (see 8.5.5).

8.2 Line Conditioning and UPS—Ship and marine ac power is often unreliable, noisy, and subject to over-voltage and under voltage conditions that can seriously damage networking equipment. Network equipment should never be connected directly to shipboard power without the protection of a line conditioner and an uninterruptible power supply (UPS). (Printers need not be connected to UPS.)

8.2.1 Line conditioners protect against over/under voltage conditions, and provide some degree of noise suppression, but do not protect against total loss of power. UPSs provide over/under voltage protection, noise suppression, and supply ac power (generated from dc batteries within the UPS) for a limited time. (The loss-of-power protection interval varies with the size of the UPS batteries, but should be designed to operate for a minimum of 30 min when the UPS is operated at the recommended 50 % rated load.)
8.2.2 Unlike shore-based ac distribution systems, ship and marine power uses an ungrounded (floating) neutral. If ordinary line conditioners or UPSs are connected to shipboard power, the grounded neutral will cause a ground-fault indication. Line conditioners and UPSs with floating neutral can be obtained, but they must be special-ordered for ship and marine service.

8.3 Electrical System Interfaces:

8.3.1 Electric Load Analysis—Prior to installation, an electrical load analysis should be performed to calculate the electrical system impact associated with the new equipment, taking into consideration any removed equipment as well.

8.3.2 Local Distribution—if adequate electrical distribution is not available to supply the new loads, install additional equipment and cable as required. If the existing electrical distribution system is modified, circuit breakers and cables should be examined for adequacy and modified or replaced as necessary to support the new loads.

8.3.3 Bonding and Grounding—Secure electrical information processing equipment and cables should be bonded and grounded.

8.3.4 Power Source for Backbone Switches—Backbone switches should be supplied ac power from two independent power sources via an automatic power bus transfer system.

8.4 Air Conditioning—Prior to installation, the ability of the existing ship’s air conditioning system (High Volume Air Conditioning (HV AC) system) to support the equipment installations in each compartment on the ship must be verified.

8.5 Special Considerations for Ship and Marine Critical Systems:

8.5.1 Shock Equipment shall meet grade “A” shock requirements. Equipment shall operate before, during and after shock conditions resulting from high impact shock testing of hardware, mounting rack, and shock mounting devices. For critical signals that cannot accept momentary disruption of a circuit, multi-mode fiber is preferred over single-mode fiber because multi-mode fiber connectors withstand shock more readily than single-mode connectors.

8.5.2 Humidity—Using commercially available hardware in environments with condensing 100% relative humidity can lead to shorting of printed circuit cards which are normally not conformally coated in commercial equipment. One solution to this problem is the use of specially treated equipment rooms (node rooms) or controlled spaces where highly reliable air conditioning is always available.

8.5.3 Temperature—Most electronic equipment is designed to temperature ranges of 0 to 30, 40, or 50°C. Ship and marine operation outside of this range can cause failure or improper operation of LED displays, hard drives, and CD-ROM drives at the low temperature extremes, and power supplies and other electronics at the higher temperature extremes. The concept noted in the previous paragraph of air-conditioned node rooms can be used to solve this problem. Temperature testing shall be conducted with the equipment operational in a controlled environment of 0 to 55°C.

8.5.4 Magnetic Field—The high magnetic fields caused by ship degaussing can disturb the displays on CRT screens. If critical information needs to be read during degaussing, consider the use of flat-panel displays instead of CRT displays.

8.5.5 Vibration Equipment shall be subjected to endurance testing at fixed frequencies based upon the critical frequencies determined from the vibration response testing. When vibration response investigation does not identify any critical frequencies, testing shall be conducted at the maximum vibration frequency of 100 Hz and 0.076 mm vibration amplitude.

8.5.6 Electromagnetic Susceptibility—The equipment shall not be susceptible to electromagnetic emission in the room or area in which it is installed.

8.5.7 Fungus/mold—The equipment shall not support fungal or mold growth.

8.5.8 Salt Fog—Equipment shall be tested to withstand salt fog when used in ship and marine locations that are susceptible to salt fog conditions.

9. Keywords

9.1 bus; client; CPU; fiber optic; I/O; peripherals; RAM; server; UTP; workstation
Standard Guide for
Ordering Low Voltage (1000 VAC or Less) Alternating Current Electric Motors for Shipboard Service—Up to and Including Motors of 500 Horsepower

This standard is issued under the fixed designation F 2361; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the required basic ordering information for low voltage (1000 VAC or less) general-purpose, commercial, universal, small and medium sized alternating current electric motors for shipboard use, up to and including motors of 500 hp.

1.2 The electric motors covered by this guide are general-purpose (GP) motors intended to drive common shipboard mechanical machinery such as fans, blowers, centrifugal and screw pumps.

1.3 This guide is not intended to be used to order special-purpose (SP) motors or definite-purpose motors (for example, cryogenic service) or motors for use in hazardous (classified) locations as defined by the National Electrical Code (NFPA 70).

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.

2. Referenced Documents

2.1 Canadian Standards Association (CSA):2
CSA Standard C390-93C Energy Efficiency Test Methods for Three-Phase Induction Motors General Instruction No.1

2.2 Institute of Electrical and Electronic Engineers (IEEE):3
IEEE Standard 45 Recommended Practice for Electrical Installations on Shipboard
IEEE Standard 112 Standard Test—Procedure for Polyphase Induction Motors and Generators

2.3 National Electrical Manufacturers Association (NEMA) Standard:4
NEMA Standard MG-1 Motors and Generators

2.4 National Fire Protection Association (NFPA):5
NFPA 70 National Electrical Code

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 closed-coupled—a special design where the motor features a face mounting flange that the pump casing mounts to, and a motor shaft extension on which the pump impeller is mounted.

3.1.2 dripproof—a machine enclosure that allows the motor to be cooled by ambient air having ventilation openings that allow operation when drops of liquid or solid particles strike the enclosure at any angle from zero to 15°.

3.1.3 drive method—the method of driving the equipment, such as direct, belt, gearbox, or chain.

3.1.4 efficiency classes—standard efficiency classes established by NEMA based on motor performance.

3.1.5 end shield—a machined flange or base which have rabbets and bolt holes for mounting equipment to the motor or for overhanging the motor on a driven machine.

3.1.6 frame size—standard sizes established by NEMA based on motor power and speed.

3.1.7 mounting arrangement—the installed operating position of the motor, such as horizontal, vertical shaft up, or vertical shaft down.

3.1.8 multi-speed—a motor that can operate at more than one speed, typically at two or three speeds.

3.1.9 NEMA design classes—design classifications designated by NEMA (See NEMA Standard MG-1) for motors that provides information to the end user on characteristics such as motor starting, torque, voltage, and so forth.

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2 Available from Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON Canada M9W1R3.
3 Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331
4 Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
5 Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.
3.1.10 **NEMA insulation classes**—NEMA system that classifies motor insulation systems by their ability to withstand a specified temperature for a specified length of time with minimum deterioration.

3.1.11 **polyphase medium motors**—motors which have windings so arranged to accept to polyphase voltage sources.

3.1.12 **service factor**—service factor for an ac motor is a multiplier, which when applied to the rated horsepower, indicates a permissible horsepower loading which may be carried under the conditions specified for the service factor.

3.1.13 **single-phase fractional horsepower motors**—motors with ratings up to 1 hp which use single-phase power.

3.1.14 **single-phase integral horsepower motors**—motors with ratings of 1 hp up to and including 10 hp, which normally use single-phase power but at the upper end of their specified range may also utilize polyphase power.

3.1.15 **slip**—the difference between synchronous speed and full load speed. Normal slip is less than 5%.

3.1.16 **speed**—the number of revolutions per minute (r/min) at which an induction motor operates, which is dependent upon the input power, frequency, and the number of magnetic poles in the machine.

3.1.17 **temperature, ambient**—the temperature of the air surrounding the machine.

3.1.18 **temperature rise**—the difference between the hot spot temperature and the ambient temperature times a constant (see NEMA MG-1).

3.1.19 **totally-enclosed air over (TEAO)**—an enclosure similar to a TEFC except the cooling air is provided by a fan that is not part of the motor.

3.1.20 **totally-enclosed fan-cooled (TEFC)**—a totally-enclosed machine equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosed parts.

3.1.21 **totally-enclosed non-ventilated (TENV)**—a machine enclosed to prevent the free exchange of air between the inside and outside of the case, but not sufficiently enclosed to be airtight.

3.1.22 **totally-enclosed water-air cooled (TEWAC)**—a totally-enclosed machine with integral water-to-air heat exchanger and internal fans to provide closed-loop cooling of the windings.

3.1.23 **universal motors**—typically small motors, which can operate on ac or dc current, or both.

3.1.24 **variable speed drive (VSD)**—a method used to permit an operator to vary the speed of a motor.

3.1.25 **weather protected**—a machine with ventilating passages so constructed as to minimize the entrance of rain, snow and airborne particles to the electrical components.

### 4. General Requirements for Electric Motor Ordering

4.1 **Electric Motor Ordering Requirements:**

4.1.1 With each electric motor ordered for marine service, provide the following, to the greatest extent practicable:

4.1.1.1 **Electrical Input**—Voltage, phases and frequency.

4.1.1.2 **Speed (Synchronous or Full Load)**—r/min.

4.1.1.3 **Power**—The horsepower of the motor must be stated as a standard NEMA rating. At a minimum, consideration should be given to the needed starting torque, capability to accelerate the load to full running speed and maximum overload.

4.1.1.4 **Enclosure**—Select in accordance with IEEE Standard 45. DP or TEFC are normally specified for below deck applications and WP for above deck applications.

4.1.1.5 **Duty Cycle**—Continuous duty is normally specified since it demands operation at an essentially constant load for an indefinitely long time. If intermittent or varying duty cycles are required, special motor selection criteria will apply.

4.1.1.6 **Ambient Temperature**—Standard motors are designed for 400°C ambient. If a higher ambient is required, this will reduce the service factor or reduce the motor rating thus requiring a larger size motor.

4.1.1.7 **Insulation Class**.

4.1.1.8 **Design Class**—NEMA designated design class.

4.1.1.9 **Service Factor (SF)**.

4.1.1.10 **Drive Method**.

4.1.1.11 **Mounting Arrangement**—If vertical, specify with or without feet.

4.1.1.12 **Mounting Flange (End Shield):**

   1. **C-face**
   2. **D-flange**
   3. **P-base**

4.1.1.13 **Rotation**—The rotation of the motor must be specified as clockwise, counter-clockwise or reversible.

4.1.1.14 **Conduit Box Location**—View from the non-shaft end of the motor:

   1. **Right (standard)**—F1
   2. **Left**—F2

4.1.1.15 **Closed-coupled**—Specify when the motor will mount the pump on a flange and the motor shaft mounts the pump impeller.

4.1.1.16 **Efficiency**—If compliance with the Energy Policy Act of 1992 is necessary, it should be stated that motors shall be furnished with a nominal efficiency as defined in Table 12-10, NEMA MG-1.

4.1.1.17 **Special Requirements**—This shall include, but not be limited to, space heaters, temperature protection, additional

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**TABLE 1 Sample Electric Motor Ordering Checklist**

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Unit, Value, Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Input</td>
<td>Voltage, Phase, Frequency</td>
</tr>
<tr>
<td>Speed</td>
<td>r/min (single speed, two speed, VSD)</td>
</tr>
<tr>
<td>Power</td>
<td></td>
</tr>
<tr>
<td>Enclosure</td>
<td>Type per NEMA MG-1</td>
</tr>
<tr>
<td>Duty Cycles</td>
<td>Continuous or Other</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Insulation Class</td>
<td>per NEMA MG-1</td>
</tr>
<tr>
<td>Design Class</td>
<td>per NEMA MG-1</td>
</tr>
<tr>
<td>Service Factor</td>
<td>1.0 or Other</td>
</tr>
<tr>
<td>Drive Method</td>
<td>Specify</td>
</tr>
<tr>
<td>Mounting Arrangement</td>
<td>Specify</td>
</tr>
<tr>
<td>Mounting Flange (end shield)</td>
<td>Yes or No</td>
</tr>
<tr>
<td>Rotation</td>
<td>OW, CCW, Reversible</td>
</tr>
<tr>
<td>Motor conduit box Location</td>
<td>F1, F2</td>
</tr>
<tr>
<td>Closed-Coupled</td>
<td>Yes or No</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Standard, High, Premium</td>
</tr>
<tr>
<td>Special Requirements</td>
<td>Specify</td>
</tr>
<tr>
<td>Other Standards</td>
<td>Specify</td>
</tr>
</tbody>
</table>
regulatory or classification society requirements. Specific specification sections and paragraphs must be cited.

4.2 Other Requirements:

4.2.1 Marine Service—Each motor specified for installation on board ship shall as a minimum comply with the requirements of IEEE Standard 45.

4.2.2 General Testing—Unless otherwise stated, all motors shall be tested in accordance with the requirements of IEEE Standard 112.

4.3 Electric Motor Ordering Checklist:

4.3.1 It is recommended that the minimum information shown in Table 1 be provided to the supplier when ordering an electric motor for marine service.

5. Keywords

5.1 general purpose motors; multi-speed motors; polyphase motors
Standard Specification for Temperature Monitoring Equipment

This standard is issued under the fixed designation F 2362; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the requirements for equipment intended to provide control input and monitoring of temperatures in general applications. Equipment described in this specification includes temperature indicators, signal conditioners and power supplies, and temperature sensors such as thermocouples and resistance temperature element assemblies.

1.2 Special requirements for Naval shipboard applications are included in the Supplementary Requirements section.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

D 3951 Practice for Commercial Packaging
E 344 Terminology Relating to Thermometry and Hydrometry

3. Terminology

3.1 Definitions—Definitions of terminology shall be in accordance with Terminology E 344.

4. Classification

4.1 General—Temperature measuring devices are generally classified as either temperature sensors or thermometers. Thermometers are not covered by this specification. Temperature sensors are classified by design and construction. Sensors may also be classified by the manner of response, basically mechanical or electrical, to a change in temperature. Mechanical response is characterized by some mechanical action as temperature changes. Electrical response is characterized by the production or change of an electrical signal or property as temperature changes. The following describes the most common types of sensors:

4.2 Thermocouples—Thermocouples are constructed in a variety of designs to provide measurement of direct or differential temperature. Thermocouples are commonly installed using a thermowell which protects the thermocouple but also delays the rapid response time characteristic of thermocouples.

4.2.1 Principle of Operation—Most thermocouples utilize two wires fabricated from dissimilar metals joined at one end to form a measuring junction that is exposed to the process medium being measured. The other ends of the wires are usually terminated at a measuring instrument which forms a reference junction. When the two junctions are exposed to different temperatures, electrical current will flow through the circuit (Seebeck Effect). The measurement of millivoltage resulting from the current is proportional to the temperature being sensed.

4.2.2 Types of Thermocouples—Thermocouples can be divided into functional classes by materials and therefore, temperature ranges. The three classes are base metal, noble metal, and refractory metal. Although many types are commonly used in industrial applications, the Instrument Society of America (ISA) has assigned letter designations to seven types. By convention, the practice of using a slash mark to separate the materials of each thermocouple wire is widely accepted. Likewise, the order in which the materials appear also denotes polarity of the wires; positive/negative when the measuring junction is at a higher temperature than the reference junction. The following are examples of typical thermocouples:

<table>
<thead>
<tr>
<th>Class</th>
<th>Type</th>
<th>Materials</th>
<th>Temperature (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal</td>
<td>J</td>
<td>Iron/constantan</td>
<td>1000°C (1832°F)</td>
</tr>
<tr>
<td>Base metal</td>
<td>T</td>
<td>Copper/constantan</td>
<td>1000°C (1832°F)</td>
</tr>
<tr>
<td>Base metal</td>
<td>K</td>
<td>Chromel/Alumel</td>
<td>1000°C (1832°F)</td>
</tr>
<tr>
<td>Base metal</td>
<td>E</td>
<td>Chromel/constantan</td>
<td>1000°C (1832°F)</td>
</tr>
<tr>
<td>Base metal</td>
<td></td>
<td>Alloys of copper, nickel, iron, chromium, manganese, aluminum, and other metals</td>
<td>1000°C (1832°F)</td>
</tr>
<tr>
<td>Noble metal</td>
<td></td>
<td>Various noble metals</td>
<td>2000°C (3632°F)</td>
</tr>
<tr>
<td>Refractory</td>
<td></td>
<td>Tungsten-rhenium, tantalum, molybdenum, and their alloys</td>
<td>2600°C (4712°F)</td>
</tr>
</tbody>
</table>

4.3 Resistance Temperature Measuring Devices—Resistance thermometers measure changes in temperature based on changes in resistance of the sensor element exposed to the temperature. Two common types are resistance temperature detectors which have metal sensor elements and thermistors which have semiconductor sensor elements.
4.3.1 Resistance Temperature Detectors (RTDs)—An RTD consists of a sensor which uses a metal wire or fiber which responds to changes in temperature by changing its resistance. The sensor is connected to a readout via a bridge circuit or other means of translating the resistance to a temperature value.

4.3.1.1 Types of RTDs—RTD designs include averaging RTDs, annular RTDs, and combination RTD-thermocouples. Averaging RTDs are characterized by a long resistance element. Annular RTDs have sensors that are designed to provide a tight fit within the inner walls of thermowells. Combination RTD-thermocouples have both an RTD and a thermocouple housed in the same sheath.

4.3.2 Thermistors—Thermistors are made of solid semiconductor materials, usually complex metal oxides, that have a high coefficient of resistance. Thermistors are available with positive and negative temperature coefficients of resistance and are usually designated PTC and NTC thermistors, respectively. The temperature range for typical thermistors is 100 to 300°C (212 to 572°F).

4.3.2.1 Types of Thermistors—Thermistors are classified by the configuration of the semiconductor material. Common types are the bead, disc, washer, and rod thermistors. Leads are attached to semiconductor materials, except where metal plated faces are used for contact to complete the circuit.

5. Ordering Information

5.1 The purchaser should provide the manufacturer with all of the pertinent application data outlined in the acquisition requirements.

5.2 Acquisition Requirements—Acquisition documents should specify the following:

5.2.1 Title, number and date of this specification,
5.2.2 Classification required,
5.2.3 Quantity of units required,
5.2.4 Type of enclosure mounting,
5.2.5 Power requirements,
5.2.6 Equipment temperature ranges,
5.2.7 Size or weight limitations,
5.2.8 Disposition of qualification test samples,
5.2.9 Product marking requirements, and
5.2.10 Special preservation, packaging, packing and marking requirements.

6. Materials and Manufacture

6.1 Temperature Sensors—The materials for all wetted parts shall be selected for long term compatibility with the process medium.

7. Physical Properties

7.1 Description—The equipment specified herein in conjunction with the thermocouples or resistance temperature measuring elements comprise a temperature instrument. The temperature monitoring equipment may consist of the following units and may be built integrally together and housed in the same enclosure:

7.1.1 Signal Conditioner—The signal conditioner shall convert the sensing element output to a continuous linear analog signal directly proportional to temperature.

7.1.2 Power Supply—The power supply shall provide excitation energy to the signal conditioner and sensor.

7.1.3 Test Device—A test device shall be furnished to provide a calibrated test signal used for calibrating the equipment.

7.2 Size and Weight Considerations—A dimensional outline of the temperature monitoring equipment showing overall and principle dimensions in sufficient detail to establish space requirements in all directions necessary for installation and servicing will greatly assist proper selection. In many applications weight is a critical limitation.

7.3 General Features—Requirements for general features shall be specified. General features consist of the following:

7.3.1 Output,
7.3.2 Equipment range,
7.3.3 Adjustments,
7.3.4 Failsafe output,
7.3.5 Isolation,
7.3.6 Enclosure,
7.3.7 Power supply requirements, and
7.3.8 Cable entrance and connection.

8. Performance Requirements

8.1 Service Life—The purchaser may have a minimum specified service life requirement. Critical service life requirements shall be specified in the acquisition requirements.

8.2 Performance Considerations—Certain performance characteristics may be deemed critical to the intended or desired function of temperature monitoring equipment. Performance tolerances are usually expressed in percent of equipment span. The following performance characteristics and environmental exposures should be tailored to each purchaser’s intended application:

8.2.1 Accuracy,
8.2.2 Repeatability,
8.2.3 Threshold and deadband,
8.2.4 Ripple,
8.2.5 Warm-up time,
8.2.6 Input resistance,
8.2.7 Supply voltage or frequency, or both,
8.2.8 Temperature error,
8.2.9 Response time,
8.2.10 Temperature,
8.2.11 Insulation resistance,
8.2.12 Vibration, and
8.2.13 Shock.

9. Workmanship, Finish and Appearance

9.1 Finish and Appearance—Any special surface finish and appearance requirements shall be specified in the acquisition requirements.

10. Number of Tests and Retests

10.1 Test Specimen—The number of test specimens to be subjected to qualification testing shall depend on the sensor design. If each range is covered by a separate and distinct design, a test specimen for each range may require testing. In instances where a singular design series may cover multiple
ranges and types, only three test specimens may need to be tested provided the electrical and mechanical similarities are approved by the purchaser. In no case, however, should less than three units, one unit each representing low, medium, and high ranges, be tested, regardless of design similarity.

11. Test Data

11.1 Test Data—All test data shall remain on file at the manufacturer’s facility for review by the purchaser upon request. It is recommended that test data be retained in the manufacturer’s files for at least three years, or a period of time acceptable to the purchaser and manufacturer.

12. Inspection

12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

12.1.1 Qualification testing, and
12.1.2 Quality conformance testing.

12.2 Qualification Testing—Qualification test requirements shall be specified where applicable. Qualification test methods should be identified for each design and performance characteristic specified. Test report documentation requirements should also be specified.

12.3 Quality Conformance Testing—Quality conformance testing is accomplished when qualification testing was satisfied by a previous acquisition or product has demonstrated reliability in similar applications. Quality conformance testing is usually less intensive than qualification, often verifying that samples of a production lot meet a few critical performance requirements.

13. Certification

13.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

14. Product Marking

14.1 Purchaser specified product marking shall be listed in the acquisition requirements.

15. Packaging and Package Marking

15.1 Packaging of Product for Delivery—Product should be packaged for shipment in accordance with Practice D 3951.
15.2 Any special preservation, packaging, or package marking requirements for shipment or storage shall be identified in the acquisition requirements.


16.1 Warranty:

16.1.1 Responsibility for Warranty—Unless otherwise specified, the manufacturer is responsible for the following:
16.1.1.1 All materials used to produce a unit, and
16.1.1.2 Manufacturer will warrant his product to be free from defect of workmanship to produce the unit.

17. Keywords

17.1 resistance temperature detector (RTD); thermistor; thermocouple

SUPPLEMENTARY REQUIREMENTS

TEMPERATURE MONITORING EQUIPMENT (NAVAL SHIPBOARD USE)

The following supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard (ASTM F 2362) and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supercedes MIL-T-15377, Temperature Monitor Equipment, Naval Shipboard, for new ship construction.

S1. Scope

S1.1 This supplement covers temperature monitoring equipment which continuously monitors and selectively indicates, at a central location, a number of temperatures at remote equipment locations on board naval ships.

S1.2 Monitoring Equipment—Monitoring equipment, in conjunction with the temperature sensor assemblies and interconnecting cabling, comprise a temperature measuring and alarm system. In order to warn operating personnel of abnormal temperature conditions, the system shall energize an audible and visual alarm when the temperature at a particular location is below or above a preset limit. Monitoring of temperatures shall be accomplished by measuring the electromotive force (emf) output of thermocouples or by measuring the signal output due to changes in resistance of temperature sensing elements. Temperature monitoring equipment shall actuate external audible alarms specified herein.

S1.3 Selective Temperature Readout Equipment—Selective temperature readout equipment, in conjunction with temperature sensor assemblies and interconnecting cabling, comprise a temperature measuring system. In order to enable operating personnel to measure a number of temperatures at remote points, the system shall enable the operator to manually select the desired point to be measured, convert the selected temperature sensor output to a signal proportional to temperature, and display this signal on a meter calibrated in temperature °C (°F). Readout of temperatures shall be accomplished by measuring the output of thermocouples or by measuring the signal output due to changes in resistance of temperature sensing elements.

S1.4 The U.S. Government preferred system of measurement is the metric SI system. However, since this item was
originally designed using inch-pound units of measurement, in the event of conflict between the metric and inch-pound units, the inch-pound shall take precedence.

S.2. Referenced Documents

S.2.1 Commercial Documents:
- ANSI C96.1 Temperature Measurement Thermocouples
- S.2.2 Government Documents:
- S.2.2.1 Military Standards:
  - MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment
  - MIL-STD-1399 Interface Standard for Shipboard Systems
  - MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for
  - MIL-PRF-19207/1 Fuseholders, Extractor Post Type, Blown Fuse Indicating, Type FHL10U
  - MIL-PRF-19207/2 Fuseholders, Extractor Post Type, Blown Fuse Indicating, Type FHL11U

S.3. Terminology

S.3.1 Definitions:
- S.3.1.1 "temperature monitoring equipment"—the necessary equipment required to continuously or selectively sense and indicate various temperatures including audible and visual alarms when specified.

S.4. Classification

S.4.1 Classification—Monitoring and selective temperature readout equipment classification shall be of following format:
Example: ASTM F2362S1-IC/A-1-RTE-40

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type</th>
<th>Alarm</th>
<th>Sensing Techniques</th>
<th>Number of Channels</th>
</tr>
</thead>
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<tr>
<td>F2362S1</td>
<td>IC/A</td>
<td>1</td>
<td>RTE</td>
<td>40</td>
</tr>
</tbody>
</table>

S.4.2 Type—The equipment shall be designated by the 3 letter symbols as follows:
- IC/A—Continuous, simultaneous monitoring of remote temperature sensors for alarm and also manual selective temperature readout.
- IC/I—Manual selective temperature readout for measuring temperatures at several remote locations.
- IC/S—Continuous, sequential scanning of remote temperature sensors for indication and alarm.

S.4.3 Alarm—The alarm technique shall be designated by a single number as follows:
1—Alarm on temperature above the set level or (exclusive or) below the set level as operator selected.
2—No alarm provision—temperature readout only.

S.4.4 Temperature Sensing Technique—The temperature sensing technique shall be designated by 3 letter symbols as follows:

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S.4.4.1 Readout Ranges—Readout ranges shall be provided as specified as follows:
(1) For RTE type sensors, the following ranges and meter scales shall be provided:
(a) 5 to 127°C (-40 to 260°F)
(b) 18 to 205°C (0 to 400°F)
(c) 18 to 427°C (0 to 800°F)
(d) 18 to 538°C (0 to 1000°F)
(2) For type TCE sensors, the following ranges and meter scales shall be provided:
(a) 5 to 127°C (-40 to 260°F)
(b) 18 to 205°C (0 to 400°F)
(c) 18 to 427°C (0 to 800°F)
(d) 205 to 816°C (400 to 1500°F)
(e) 260 to 1093°C (500 to 2000°F)

S.4.5 Number of Channels—The number of channels, corresponding to the number of remote sensors that monitored shall be designated by its numerical value.

S.5. Ordering Information

S.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data shown in accordance with S.5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S.5.2 Acquisition Requirements—Acquisition documents should specify the following:
(1) Title, number and date of this specification,
(2) Classification required,
(3) Quantity of items required,
(4) Number of temperature sensors to be monitored,
(5) Setting of alarm channels, if other than 93.3°C (200°F),
(6) Height and weight of equipment assembly,
(7) Number of remote resistance temperature sensors or remote thermocouple temperature sensors monitored by equipment,
(8) Equipment alarm and readout temperature range,
(9) Accuracy or other performance requirements,
(10) Disposition of qualification test samples, and
(11) Unique preservation, packaging and marking requirements.

S.6. Materials and Manufacture

S.6.1 Unless otherwise specified, equipment shall be fabricated from corrosion resistant materials compatible with system piping materials and process medium.

S.7. Physical Properties

S.7.1 Enclosure Assembly:
- S.7.1.1 Temperature Monitor Equipment—Equipment enclosure assembly shall be of sheet metal, splash-proof construction, and shall be suitable for either panel or bulkhead mounting. Splash-proof construction shall be such that water or solid particles directed at the enclosed equipment or its mounting surface shall have no harmful effect on equipment operation.
S7.1.2 Continuous Parallel Monitoring (IC/A)—Enclosure assembly for IC/A monitor equipment shall contain one temperature readout module and the number of alarm modules required to provide the number of alarm channels specified, up to a maximum of 60. Modules shall be readily removable from the enclosure assembly by means of integral plug-in features operable from the front of the enclosure. Access to the interior or back of the enclosure assembly shall not be required to accomplish removal of any module.

S7.1.3 Temperature Readout Module—The temperature module shall be a temperature readout device and associated circuits. Necessary controls shall be located on the front panel of the module.

S7.1.4 Alarm Module (IC/A and IC/I)—Indicator lights and controls shall be located on the front panel of each alarm module to perform the following functions. Multi-position switches may be utilized to combine control functions specified.

1. Power on light (white lens).
2. Alarm light for each temperature monitoring channel (red lens).
3. External alarm cut-out (silence) switch for each temperature monitoring channel.
5. External alarm cut-out (silence) switch for temperature monitoring channels (one per equipment).
6. Alarm circuit reset switch: one per module (if required).
7. Test switch to verify continuity of alarm circuit, alarm light, and temperature sensor (one per module).
8. Read (indicate) light on each temperature monitoring channel to light when it has been selected at the readout module.

S7.1.5 Access (IC/A)—Electrical connection between alarm and readout modules and between modules and the other circuits within the enclosure assembly shall be by means of quick-disconnect connectors. Required auxiliary circuits, such as the power supply, shall be located within the enclosure assembly in such a location as to be readily accessible from the front of the enclosure assembly. Required controls and indicators, associated with the power supply, shall be on the front panel. Fold down or slide drawer chassis construction may be used. Terminals and terminal boards shall be provided for interconnection to ships power, temperature sensors, and external audible alarm. These terminals shall also be located to be accessible from the front of the enclosure assembly. Three 2.44 m (8 ft) long cable assemblies shall be provided and stowed securely inside each equipment enclosure. With these cable assemblies, it shall be possible to remove any one alarm module and the power supply, readout, alarm, and calibration modules to operate the equipment in a normal manner on a work bench away from the installed console. These cable assemblies shall only be required to obtain access for special testing, trouble shooting, and repair.

S7.1.6 Manual Selective Temperature Readout Equipment (IC/I)—Enclosure assembly shall contain the temperature indicating meter, selector switch for selecting the desired temperature sensor to be read, all required, associated functional circuits and parts, and terminals for interconnection to external power and temperature sensors.

S7.1.7 Continuous Scanning Monitoring (IC/S)—Enclosure assembly for IC/S shall contain a readout, a micro processor, input multiplexers, A/D converters, and alarm circuits required to provide the number of channels specified, up to a maximum of 60. Operating controls and the readout shall be accessible from the front panel. A provision shall be included whereby the function of the front panel controls can be disabled to prevent tampering by unauthorized personnel.

S7.1.8 Temperature Monitor Equipment (IC/A)—One identification plate shall be provided for each enclosure assembly. Individual identification plates shall be provided on each module (alarm and indicator unit) showing the location of the associated temperature sensing element, next to each alarm light, and identifying the function of controls and indicators located on the front of each module. As an alternate, identification plates showing location of temperature sensor elements may be provided on the overall equipment frame adjacent to each module location. Plates shall also provide for indicating the proper scale to use on the readout for each channel if a dial type meter is used. Adjustment, calibration, setting, and standardization controls located within the enclosure assembly, shall also be identified by means of identification plates. Temperature sensor connection terminals shall be marked to correspond with the position identification for monitor point.

S7.1.9 Selective Temperature Readout Equipment (IC/I)—The position of all selector switches shall be marked to identify the temperature sensor selected to be measured. Adjustment, calibration, and sensor connection terminals located within the enclosure assembly shall be identified and marked.

S7.1.10 Continuous Scanning Monitoring (IC/S)—The equipment display shall identify the location of the temperature element when an alarm condition occurs.

S7.2 System Requirements:

S7.2.1 Temperature Monitor Equipment (IC/A)—IC/A temperature monitor equipment shall provide for continuous paralleled monitoring of up to 60 temperature sensors. Equipment shall be modular, with individual modules having plug-in features as specified in S7.1.2. There shall be at least 3 types of modules:

1. Monitor and alarm,
2. Readout, and
3. Power supply module.

Each monitor and alarm module shall monitor 4 temperature sensors. Equipment shall be capable of operating, as specified herein, with each of the 60 temperature alarm set points adjusted for a different temperature setting. Any alarm may be activated regardless of the state of any other alarm. For purposes of standardization, the factory setting shall be approximately 93.3°C (200°F) for points, unless otherwise specified in the acquisition requirements.

S7.2.2 Visual Alarm—Each monitor point shall be uniquely associated with a specific remote temperature sensor and shall have its own individual indicating light. When the temperature at the point being monitored reaches a predetermined temperature setting (alarm point), the indicator light shall be energized and remain energized until manually reset.
S7.2.3 *Audible Alarm*—One relay or electronic switch having 5 A minimum rating DPDT operation shall be provided for supplying 115 V alternating current (ac) power for actuating an external audible alarm simultaneously with activating the visual alarm. The alarm relay switch shall be wired to the panel terminal boards in the cable entrance stuffing box. The audible alarm shall be activated when any one or more of the temperatures being monitored reaches the predetermined (alarm) setting. Each channel shall provide a manual switch for cutting out the audible alarm for its own monitoring point. This cut-out shall not prevent any of the other channels from sounding the audible alarm should the temperature at any other monitored point reach the predetermined (alarm) setting. A single, master cut-out switch with associated indicator light shall be provided, which will disable the sounding of the external audible alarm for the entire system.

S7.2.4 *Independent Action*—The monitoring and alarm action of individual points shall be independent of each other. Action of indicating an alarm condition at one or more monitor points shall not prevent the system (equipment) from indicating an alarm condition at other monitor points.

S7.2.5 *Temperature Readout*—The temperature readout device and channel selector switch shall be provided in a readout module. The selector switch shall be depressed to turn so that momentary contact is not made with intermediate channels. The continuous, automatic monitor and alarm capability of the system shall not be affected by the selection of a temperature sensor for reading. When a channel temperature reading is being taken, the alarm feature of all points including the one being measured shall be maintained. The operation of the readout module shall not depend on balancing motors, slidewires, potentiometers, or similar devices. The use of potentiometers shall be limited to test, adjustment, and calibration purposes only.

S7.2.6 *Test Feature*—A test switch shall be provided for each monitor and alarm module for testing alarm lights and continuity of each temperature sensor and alarm circuits of that module. When the switch is operated to the “test” position, the channel alarm light shall indicate an alarm condition. Failure of the channel alarm light on the module to light shall indicate an open circuit in the lamp, temperature sensor, or in the associated alarm circuit. This test operation shall not change the normal state of the alarm relays or external relays.

S7.2.7 *Fail Safe Design*—The IC/A temperature monitor equipment shall have an inherent “fail safe” feature. An open circuit in the external temperature sensor or its connecting cabling shall result in an alarm condition.

S7.2.8 *Calibration and Setting of Alarm Point*—Design of the IC/A temperature monitor equipment shall be such as to facilitate calibration and adjustment of the individual alarm set points. Self calibration capability shall be an inherent design feature. Test jacks shall be provided to facilitate direct connection to external instrumentation for test, calibration, and trouble shooting. Calibration, alarm set point adjustment and access to the test jacks shall not require disassembly or changes to the electrical wiring connections.

S7.2.9 *Cold Junction Compensation*—Cold junction compensation for equipment for thermocouple sensing shall be self-contained, automatic, and shall be referenced to 0°C (32°F).

S7.2.10 *Lead Length Compensation*—Equipment for resistance temperature sensing shall provide an input terminal for 3 wire sensor configuration. A means shall be provided to compensate for the resistance of interconnecting wiring between sensor and monitor equipment. This compensating provision and associated sensor input terminal configuration shall be arranged that it can be easily by-passed (removable jumper, alternate terminals, or similar means) for use with 2 wire resistance temperature elements. Equipment for thermocouple sensing shall provide for thermocouple lead length compensation. Accuracy, calibration, and response time shall be independent of thermocouple extension lead length.

S7.2.11 *Size and Weight*—Individual modules (alarm or readout) shall not exceed 15.24 cm (6 in.) in height, 7.62 cm (3 in.) in width, and 30.48 cm (12 in.) in depth. Total weight per module shall not exceed 5.44 kg (12 lb). The equipment assembly, containing the required number of alarm modules, the readout module, and power supply module shall not exceed 50.8 cm (20 in.) in width, and 35.6 cm (14 in.) in depth. The height and weight, determined by the number of temperatures the equipment is designed to monitor, shall be as specified in the acquisition requirements. The equipment assembly, containing the required number of alarm modules to monitor 60 temperatures, shall not exceed 129.6 cm (51 in.) in height. Total weight shall not exceed 90.7 kg (200 lb). For a 40 point monitor system, the equipment assembly shall not exceed 91.44 cm (36 in.) in height, and weight shall not exceed 68 kg (150 lb).

S7.2.12 *Selective Temperature Readout Equipment (IC/I)*—Equipment shall provide for the manual selection of any one of several remotely located temperature sensors and converting the signal output of the selected sensor to the signal required for display on a read-out device, calibrated in °C (°F). The operation of the readout equipment shall not depend on balancing motors, slide-wires, potentiometers, or similar devices. Use of potentiometers shall be limited to test, adjustment, and calibration purposes only. The equipment shall facilitate calibration without disassembly or changes to the electrical wiring connections. Test jacks shall be provided to permit direct connection to test and calibration instruments. An inherent “fail safe” feature shall be incorporated which will result in an off-scale (high or low) reading to signal a failure in the manual selector, associated readout circuits, or an open or short in the external temperature sensor.

S7.2.12.1 *Size and Weight*—Selective temperature readout equipment assembly shall not exceed 30.48 cm (12 in.) in width, 30.48 cm (12 in.) in height, and 35.6 cm (14 in.) in depth. The total weight shall not exceed 18.14 kg (40 lb).

S7.2.13 *Continuous Scanning Monitoring, Indicating, and Alarm Equipment (IC/S)*—IC/S temperature monitor equipment shall provide for continuous scanning via micro processor of up to 60 temperature sensors. Equipment shall be modular, with individual modules having plug-in features. The equipment shall scan at a rate which will allow all channels to be
scanned in 5 s or less. Alarm set points and temperature input characteristics shall be able to be re-programmed from the front panel. The equipment shall be capable of annunciating alarms regardless of number (up to 60) and regardless of previous alarm history.

S7.2.14 Number of Readout Points (IC/A, IC/I, and IC/S)—The number of remote resistance temperature sensors or remote thermocouple temperature sensors monitored by the equipment shall be specified in the acquisition requirements.

S7.3 Parts Requirements—Electrical parts, mechanical parts, processes, and material shall be selected and applied to meet the requirements herein.

S7.3.1 Batteries—Batteries shall not be used.

S7.3.2 Electrical Indicating Meters—Electrical indicating meters shall be high-impact shock resistant, watertight, or hermetically sealed types, in accordance with one of the following:

1. 11.43 cm (4-1/2 in.) 250º nominal scale length.
2. Panel mounted, edgewise type.

S7.3.3 Digital Readout—Digital meters utilized in lieu of an electrical indicating meter (analog type readout) shall have a minimum of 4 digits. The meters shall be high-impact shock resistant, and watertight, or hermetically sealed.

S7.3.4 Fuses—Fuses shall be selected so that the overload blowing characteristics and short circuit interrupting capacity matches the overload protection requirements of the equipment and wiring being protected and the short circuit capacity of the supply circuit.

S7.3.5 Fuse Mounting—Fuses shall be mounted in panel mounted, indicating type fuse-holders. Fuse-holders FH10 in accordance with MIL-PRF-19207/1 or FH11 in accordance with MIL-PRF-19207/2 are preferred types.

S7.3.6 Terminal Boards and Mounting—Terminal boards shall be stud type and shall be secured only by bolts (machine screws) and shall be capable of ready removal and replacement. They shall be accessible from the front of the enclosure with the front cover plate removed or access door open.

S7.3.7 Switches—Switches shall be selected so that rated currents and voltages (make, break, carry) are not exceeded in the intended application, as well as for their ability to withstand the shipboard environments. Rotary switches are preferred for power circuit interruption. Readout channel selector switch shall be a "push to turn" type so that momentary contact is not made with intermediate channels while turning the switch.

S8. Performance Requirements

S8.1 Calibration and Accuracy—Temperature monitoring equipment, selective temperature readout equipment, and continuous scanning temperature monitoring equipment shall comply with the calibration and accuracy requirements specified below. Equipment performance requirements specified herein are specified on the basis of simulating the signal output of the appropriate temperature sensors and applying this signal to the input terminals (temperature sensor terminal points) of the equipment.

S8.1.1 Accuracy of Alarm Set Point—Temperature monitoring equipment (IC/A, IC/I, and IC/S) shall permit the setting of the alarm point at any value over the designated temperature span. The error band of the alarm level setting shall be one-half the error band of the temperature readout on any full scale range.

S8.1.2 Accuracy of Readout—The readout error of the equipment shall not exceed ±2 % of the readout range for any readout range setting. The temperature indicated on the readout device shall be within ±2 % of the temperature equivalent to the simulated temperature sensor output in ohms or millivolts, as applicable.

S8.2 Ambient Temperature Error—The change in temperature reading (temperature error) of the equipment due to any changing ambient temperature from 4.5 to 65ºC (40 to 149ºF) shall not exceed 0.18 (0.1) % of full scale per °C (°F) change in ambient temperature.

S8.3 Response Time:

S8.3.1 Alarm Circuits (IC/A and IC/I)—The alarm shall be actuated within 0.1 s when a step signal change of 1.5 % of full scale is applied when the monitoring systems are reading 1.4 % of full scale below the alarm setting for any alarm setting from 5 to 100 % of full scale.

S8.3.2 Alarm Circuits (IC/S)—The alarm shall be actuated on the first scan cycle after the alarm condition appears at the input of the equipment. Alarms shall be programmable to actuate either above a set condition or below a set condition.

S8.3.3 Temperature Readout—Equipment shall display the steady state temperature reading ±2.0 % in less than 3 s when a step signal equivalent to 80 % (from 10 to 90 %) of full temperature span is applied to the temperature sensor input terminals of the temperature monitoring equipment console.

S8.3.4 Compensation for RTE—Equipment shall provide for 3 wire temperature sensor inputs. Means shall be provided to compensate for the resistance of interconnecting wiring between temperature sensor and the indicator equipment. Compensating provision and associated sensor input terminal configuration shall be so arranged that it can be easily bypassed (removable jumper, alternate terminals, or similar means) for use with 2 wire uncompensated resistance temperature sensors.

S8.3.5 Compensation for TCE—Cold junction compensation shall be self-contained, automatic, and shall be reference to 0ºC (32ºF).

S8.4 Operation:

S8.4.1 Temperature Monitor Equipment—When the equipment is operated under nominal conditions simulating shipboard service (see S11.3), equipment operation shall comply with the following:

1. Individual visual alarm indicators light when associated test switch is operated (applicable to IC/A and IC/S equipment).

2. Test, reset, and audible alarm cut out switches operate as required.

3. Indicator reads required temperature when test and select (or indicate as applicable) switches are operated. Readout accuracy shall be in accordance with S8.1.2.

4. Alarm indication activated with temperature sensor terminals open or short circuited, except instruments for thermocouple sensors need not detect a short.

S8.4.2 Selective Temperature Readout Equipment—When the equipment is operated under nominal conditions simulating
shipboard service (see S11.3), equipment operation shall comply with the following:

(1) Accuracy of readout (see S8.1.2).

(2) Selector switch operates in accordance with S8.4.1.(3).

(3) Indicator scale is driven to either extreme low or high with temperature sensor terminals open or short circuited.

S8.4.3 Power Supply Requirements—Equipment shall operate normally from type I power as defined in MIL-STD-1399, Section 300. Nominal power input voltage and frequency shall be 115 V, 60 Hertz (Hz), single phase. Power line transients and spikes with magnitudes, duration, repetition rates, and decay characteristics as specified in MIL-STD-1399, Section 300 shall not cause equipment damage or affect equipment operation. The maximum difference in indicator reading and alarm setting level at any voltage and frequency condition and nominal (115 V, 60 Hz) with the same input, shall not exceed 1/2 of 1 % of full scale on all ranges.

S8.5 Warm-up Time—Transducer output shall attain a value within ±1 % of the steady-state output with no overshoot in excess of 1 %. Output shall reach this band in 30 min or less and shall remain in this band (see S11.4).

S8.6 Inclination—Maximum deviation of indication resulting from inclination shall not exceed 1.0 % (see S11.5).

S8.7 Enclosure—There shall be no evidence of water leakage into the equipment enclosure (see S11.6).

S8.8 Insulation Resistance—The insulation resistance shall be not less than 10 megohms between power input lines and ground (hull).

S8.9 Shock—The temperature monitoring equipment shall show no evidence of mechanical or electrical damage or loosening of parts, when exposed to shock in accordance with MIL-S-901.

S8.9.1 Temperature Monitor and Readout Equipment (IC/A, IC/I, and IC/S)—Operating controls shall not change status during shock. There shall be no transfer of switch or relay contacts or change in selector switch position during shock. After shock, without any adjustments, the equipment shall meet the following requirements:

(1) Alarm set point accuracy as specified in S8.1.1 (as applicable).

(2) Indicator accuracy in accordance with S8.1.2.

(3) Operation shall be in accordance with S8.4.

S8.10 Vibration—Temperature indicating and monitoring equipment shall operate in accordance with the requirements herein when exposed to type I environmental vibration of MIL-STD-167-1. Equipment range and accuracy requirements shall be demonstrated during and after completion of vibration. Equipment shall show no evidence of mechanical or electrical damage or loosening of parts. Operating controls and relays shall not change status during vibration. There shall be no momentary or permanent transfer of switch or relay contacts or change in selector switch position during vibration.

S8.11 Temperature—Equipment shall operate in accordance with S8.4 when exposed to ambient temperature conditions from 0 to 65°C (32 to 149°F). The equipment shall not be damaged in a non-operating condition when exposed to ambient temperatures of -40 to 70°C (-40 to 158°F).

S9. Workmanship, Finish, and Appearance

S9.1 Cleaning and Surface Finishes—Surfaces of castings, forgings, molded parts, stampings, machined and welded parts shall be free of defects such as cracks, porosity, undercuts, voids and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burr-through. There shall be no warpage or dimensional change due to heat from welding operation. There shall be no damage to adjacent parts resulting from welding.

S10. Number of Tests and Retests

S10.1 The number of tests and retests, if any, shall be specified in the acquisition requirements.

S11. Test Methods

S11.1 Calibration and Accuracy—Monitor and readout equipment calibration and accuracy measurements shall be accomplished by simulating temperature sensor signal output over the designated temperature span. Simulated signal for equipment using the resistance sensing technique shall be resistance values as specified in Appendix B and shall be simulated by a resistance decade (or similar device) having an accuracy of ±0.055 Ω. The simulated signal for equipment using the thermocouple sensing technique shall be millivolts (mV) as specified in ANSI C96.1 and shall be simulated by a stable direct current (dc) voltage source having an accuracy of ±0.025 mV.

S11.1.1 Accuracy of Alarm Set Point—Alarm set points shall be calibrated and adjusted in accordance with the instructions contained in the technical manual furnished with the equipment. The accuracy of the alarm set point shall be checked at 5 different temperatures approximately equally spaced over the temperature span for each alarm channel. A signal simulating the temperature sensor output shall then be applied to the equipment input terminals. The accuracy of the alarm set point shall be checked with both increasing and decreasing signals. The signal required to actuate the alarm shall be within the limits specified in S8.1.1.

S11.1.2 Accuracy of Readout—The accuracy of the readout portion of equipment types shall be determined at approximately equally spaced intervals over each readout temperature span. The reading, at each simulated temperature input, shall be as specified in S8.1.2.

S11.1.3 Lead Resistance Compensation—For equipment which operates with RTE sensors, one of the measurements specified in S11.1.1 and S11.1.2 shall be repeated by inserting a resistance in series with each lead of the resistor simulating the RTE to simulate lead resistance. The resistance in each lead shall be any value between 20 and 30 Ω, but the resistance for each lead shall be equal to each other within 0.1 Ω.

S11.2 Response Time:

S11.2.1 Alarm Circuits—Compliance with S8.3.1 shall be demonstrated by testing at 10, 20, 50, 90, and 100 % of the full alarm setting range.

S11.2.2 Temperature Readout—A step input signal, equal to 80 % of the temperature span (from 10 to 90 % of the span) for
shall be subjected to the following examinations and tests:

S11.3 Operation (Monitor and Readout Equipment)—Equipment shall be energized with nominal voltage and frequency (115 V, 60 Hz) and allowed to stabilize for at least 30 min. Input signals, simulating temperature sensor outputs equivalent to approximately mid-range of the temperature span, shall be connected to all equipment input terminals. Equipment controls shall then be actuated in turn to verify compliance with S8.4.1 and S8.4.2. Indicator readings shall be noted and recorded. The supply voltage and frequency shall then be adjusted to the lower limit of permissible variation (see S8.4). Equipment shall be stabilized at this input power for at least 15 min and indicator reading shall be noted and recorded. Supply voltage and frequency shall then be adjusted to the higher limit, stabilized for at least 15 min, and the indicator reading noted and recorded. Temperature sensor inputs during these tests shall remain constant. The change in indicator reading, due to variations in input power shall be within the limits specified in S8.4.

S11.4 Warm-up Time—Test shall be conducted to determine the elapsed time between the application or line power to the equipment and the point at which the indication reaches the conditions specified in S8.5.

S11.4.1 The transducer shall be placed in an ambient temperature of 25 ± 2°C (77 ± 3.6°F) for not less than 2 h de-energized. Recording equipment and other auxiliary equipment shall be energized to assure complete warm-up. A simulated signal equal to 80 % of span shall be applied and maintained constant during this test. Performance shall conform to S8.5.

S11.5 Inclination—The equipment shall be inclined for a period of at least 1 min in each of the following positions:

1. 45° forward
2. 45° backward
3. 45° to the left
4. 45° to the right

In each position a reference measurement (see S11.1) shall be made. Performance shall conform to S8.6.

S11.6 Enclosure—The enclosure shall be subjected to a solid stream of water from a 2.54 cm (1 in.) nozzle at 246 L (65 gal) per minute at a distance from the equipment of approximately 3.05 m (10 ft). The water stream shall be directed at all surfaces of the enclosed equipment and its mounting surface for a minimum of 5 min. Performance shall conform to S8.7.

S11.7 Insulation Resistance—Insulation resistance shall be determined with a test potential of 50 Vdc applied for a minimum of 60 s.

S11.8 Shock—Equipment and sensor assemblies shall be tested in accordance with the high-impact shock test specified in MIL-S-901 for grade A, class I, type C equipment.

S11.8.1 Monitor and Readout Equipment—The equipment shall be energized during the test with nominal voltage and frequency (115 V, 60 Hz) and sensor input signals shall be 80 % of span. During the test, all operating controls shall be observed for change in status. After the shock test, equipment shall be subjected to the following examinations and tests:

1. Alarm set point accuracy (see S11.1.1),
2. Readout accuracy (see S11.1.2),
3. Operation at nominal voltage and frequency (see S11.3),
4. Examination for evidence of mechanical damage or loosening of parts.

S11.9 Vibration—Equipment and sensor assemblies shall be tested in accordance with type I vibration of MIL-STD-167-1. Energization, input signals, observations during test and examinations after vibration shall be as specified in S11.8 for the shock test. IC/A system shall have the alarm point set within 4 % of full scale of the incoming temperature level. The temperature level shall be at 90 % of full scale. If an alarm occurs during vibration, any vibration test is a failure and corrective action is required. Frequency variation tests of MIL-STD-167-1 are required with the same settings. It shall be demonstrated that vibration from 1 to 50 Hz in accordance with MIL-STD-167-1 shall not cause alarm.

S11.10 Temperature:

S11.10.1 Operating—The equipment shall be subjected to the following temperature cycles:

<table>
<thead>
<tr>
<th>Period (h)</th>
<th>Temperature (°C)</th>
<th>Environment</th>
</tr>
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<tbody>
<tr>
<td>6</td>
<td>0°C (32°F)</td>
<td>Chamber</td>
</tr>
<tr>
<td>6</td>
<td>65°C (149°F)</td>
<td>Chamber</td>
</tr>
<tr>
<td>6</td>
<td>25°C (77°F)</td>
<td>Stable room or chamber</td>
</tr>
</tbody>
</table>

Cycle periods shall be measured from the time the temperature is stabilized. All tests within a 6-h period shall be continuous. Performance during and after the tests shall conform to S8.11.

S11.10.2 Non-operating—The equipment shall be held at each of the two temperature extremes for a period of 24 h. Performance after the test shall conform to S8.11.

S12. Inspection

S12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

(a) Qualification testing,

(b) Quality conformance testing.

S12.2 Qualification—Qualification tests shall be conducted at a laboratory satisfactory to the purchaser. Qualification tests shall consist of the general examination and the tests specified in Table S1 and shall be conducted on equipment produced with techniques and procedures normally used in production.

S12.2.1 Qualification Sample—Monitor and Readout Equipment—One sample of each type and temperature sensing

<table>
<thead>
<tr>
<th>Examination and Test</th>
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<th>Test</th>
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<tr>
<td>Calibration and accuracy</td>
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<td>S11.1</td>
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<td>Response time</td>
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<td>Operation (Monitor and Readout Equipment)</td>
<td>S8.4</td>
<td>S11.3</td>
</tr>
<tr>
<td>Warm-up time</td>
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<td>Inclination</td>
<td>S8.6</td>
<td>S11.5</td>
</tr>
<tr>
<td>Enclosure</td>
<td>S8.7</td>
<td>S11.6</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S8.8</td>
<td>S11.7</td>
</tr>
<tr>
<td>Shock</td>
<td>S8.9</td>
<td>S11.8</td>
</tr>
<tr>
<td>Vibration</td>
<td>S8.10</td>
<td>S11.9</td>
</tr>
<tr>
<td>Temperature</td>
<td>S8.11</td>
<td>S11.10</td>
</tr>
</tbody>
</table>
technique with the maximum number of channels for which qualification is sought shall be submitted for examination and test.

S12.2.1.1 Extent of Qualification—Qualification of an equipment type will also be extended to equipment of the same design, type, and sensing technique, with lesser number of channels.

S12.2.2 Test Routine—Equipment submitted for qualification testing shall be subjected to the tests shown in Table S1 in the order listed. Failure of an equipment to comply with any of the requirements listed shall cause refusal to grant qualification.

S12.2.3 Disposition of Qualification Samples—Samples subjected to qualification testing shall be considered consumed and non-deliverable as part of the contract. Final disposition of qualification samples shall be specified in the acquisition requirements.

S12.3 Quality Conformance Testing—The sample equipment or sensor assemblies selected shall be subjected to the examinations and tests listed in Table S3. Examinations and tests shall be performed in the order listed.

S12.3.1 Lot—Equipment of the same type presented for quality conformance inspection at one time shall be considered a “lot.” The lot may include the entire contract quantity, or it may be the production of any convenient time period. Each equipment shall be subjected to general examination and accuracy test.

S12.3.2 Sampling—A sample of equipment shall be selected from each lot in accordance with Table S2 and subjected to the examinations and tests specified in Table S3. If the number of nonconforming equipment in any sample exceeds the acceptance number for that sample, the lot represented by the sample shall be rejected.

S12.4 Test Conditions—Except for those tests where the following factors are the variables, tests shall be conducted with the equipment operating under the following conditions:

(1) The ambient temperature shall be 25 ± 3°C (77 ± 5.4°F), and the relative humidity shall be between 25 and 50 %.

(2) The supply voltage shall be 115 V nominal.

(3) The supply frequency shall be 60 Hz nominal.

S12.5 General Examination—The temperature monitoring equipment shall be given a thorough examination to determine that it conforms to this specification and the approved drawings with respect to material, finish, construction, assembly, dimensions, workmanship, marking, identification, and information plates. This examination shall be limited to those examinations that may be performed without disassembling the unit in such a manner that its performance, durability and appearance would be affected. This examination shall include a mechanical check of all operating controls and adjustments, as applicable.

S13. Certification

S13.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test result shall be furnished. It is recommended that all test data remain on file for three years at the manufacturer’s facility for review by purchaser upon request.

S14. Product Marking

S14.1 Product marking requirements shall be specified in the acquisition requirements.

S15. Packaging and Package Marking

S15.1 Packaging and package marking shall be in accordance with Section 15.


S16.1 Warranty—Special warranty requirements shall be specified in the acquisition requirements. Otherwise, the standard commercial warranty applies.
S17. Scope

S17.1 This specification covers the requirements for signal conditioners and electrical power supplies used in conjunction with thermocouples and resistance temperature element assemblies for naval ships. It does not include the design of the sensing elements and wells or the requirements for the readout or display.

S17.2 This specification defines equipment intended to provide control input and monitoring of temperatures for shipboard engineering plants.

S17.3 The U.S. Government preferred system of measurement is the metric SI system. However, since this item was originally designed using inch-pound units of measurement, in the event of conflict between the metric and inch-pound units, the inch-pound units shall take precedence.

S18. Referenced Documents

S18.1 Commercial Documents:

S18.2 Government Documents:
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)

S18.2.1 Military Standard:
MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)

S18.2.2 Military Specifications:

S19. Terminology

S19.1 Definitions:
S19.1.1 thermocouple, shall be as defined by S34.
S19.1.2 resistance, shall be as defined by Section S34.
S19.1.3 deadband, the range through which the measurand can be verified without a change in output.
S19.1.4 static error band, the maximum deviation of sensor output from the straight line drawn through the coordinates of the lower span limit at specified output, and the upper span limit at specified output expressed in percent of span.

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S20. Classification

Temperature monitoring equipment shall consist of a series of designs which shall be assigned and listed in the format below.

Example: ASTM F2362S17-TRE-4H-YES

<table>
<thead>
<tr>
<th>Specification Type</th>
<th>Input Range</th>
<th>Alarm and Repeater Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2362S17 TRE</td>
<td>4H</td>
<td>YES</td>
</tr>
</tbody>
</table>

S20.1 Type—Temperature measurement equipment shall be designated by the three letter symbols as follows:

TRE—Temperature Resistance Equipment, platinum
TTE—Temperature Thermocouple Equipment, type K

S20.2 Input Range—The temperature range in degrees Fahrenheit (°F) shall be designated by its numerical value (see S20.2.1.1 and S20.2.2.1).

S20.2.1 Temperature Resistance (Type TRE) Input:
S20.2.1.1 Ranges—Equipment temperature range shall be as specified in the acquisition requirements. Ranges shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Range</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40 to 127°C (-40° to 260°F)</td>
<td>26</td>
</tr>
<tr>
<td>-18 to 205°C (0° to 400°F)</td>
<td>4H</td>
</tr>
<tr>
<td>-18 to 538°C (0° to 1000°F)</td>
<td>1K</td>
</tr>
</tbody>
</table>

S20.2.1.2 Excitation Current—The maximum current through the resistance temperature element shall be 6 ma, dc.

S20.2.1.3 Lead Wire Resistance Compensation—The equipment input for resistance sensing technique shall be of three-wire configuration. A means shall be provided to compensate for the factors which introduce error such as self heating and the resistance of interconnecting wiring between the sensor and signal conditioner.

S20.2.2 Temperature Thermocouple (Type TCE) Input:
S20.2.2.1 Ranges—Equipment temperature range shall be as specified in the acquisition requirements. Ranges shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Range</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40 to 93°C (-40° to 200°F)</td>
<td>2H</td>
</tr>
<tr>
<td>-18 to 205°C (0° to 400°F)</td>
<td>4H</td>
</tr>
<tr>
<td>-18 to 538°C (0° to 1000°F)</td>
<td>1K</td>
</tr>
<tr>
<td>205 to 649°C (400° to 1200°F)</td>
<td>12H</td>
</tr>
<tr>
<td>260 to 816°C (500° to 1500°F)</td>
<td>15H</td>
</tr>
</tbody>
</table>

S20.2.2.2 Cold Junction Compensation—Cold junction compensation for thermocouple sensing technique shall be automatic and shall be referenced to 0°C (32°F).

S21. Ordering Information

S21.1 The purchaser shall provide the manufacturer with all of the pertinent application data shown in accordance with S21.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S21.2 Acquisition Requirements—Acquisition documents should specify the following:
S22. Materials and Manufacture

S22.1 Except where specifications are referenced, materials shall be in accordance with commercial specifications having material compositions suitable for service in the shipboard marine environment.

S23. Physical Properties

S23.1 Description—The equipment specified herein in conjunction with the thermocouples or resistance temperature elements specified in Appendix B comprise a temperature instrument. The temperature measurement equipment generally consists of the following units:

(1) Signal Conditioner—The signal conditioner shall convert the sensing element output to a continuous linear analog signal directly proportional to temperature.

(2) Power Supply—The power supply shall provide excitation energy to the signal conditioner and sensor.

(3) Test Device—A test device shall be furnished to provide a calibrated test signal used for calibrating the equipment.

The various assemblies of temperature measurement equipment shall be built integrally together and housed in the same enclosure.

S23.2 Output—The electrical signal output of the equipment shall be dc, directly proportional to temperature input. The output shall be 4 to 20 ma, dc into an external resistance of 550 ± 10 % σ.

S23.3 Calibration Means—A means shall be provided to monitor equipment output corresponding to temperature input to permit in place calibration by one man. Each temperature instrument shall contain a test switch and a temperature detector simulator capable of supplying a test signal into the instrument circuitry. This test device shall have a calibrated dial and shall replace the detector when the instrument is in the test mode. The signal from this simulator shall be of sufficient accuracy to determine static error band (see S24.2) and repeatability (see S24.3). Test jacks shall be provided to monitor the equipment output and detector output. Placing the instrument in the test mode shall allow remote monitoring of the detector. Calibration shall be effected without the necessity of electrical disconnection.

S23.4 Equipment Range—Equipment range shall be determined by means of an interchangeable assembly or internal adjustments.

S23.5 Adjustments—Tamper-proof adjustments for zero and span shall be provided for calibration purposes. The number of adjustments shall be kept to a minimum, consistent with the operation and maintenance of the equipment and the elimination for the selective matching of parts.

S23.6 Fail Safe Output—If the input of the signal conditioner is open circuited, the output shall drive upscale or downscale, the choice of which shall be made by means of a link.

S23.7 Isolation—Input and output circuits shall be isolated from each other and from ground.

S23.8 Enclosure—Temperature measurement equipment shall be mounted in a junction box. The junction box may be in accordance with MIL-J-24142 and MIL-J-24142/3. At a minimum, the size, mounting, and cable interface shall be per MIL-J-24142 and MIL-J-24142/3. All adjustments and test points shall be accessible when the cover is removed. Temperature measurement equipment shall be designed for bulkhead or bracket mounting.

S23.9 Weight—The weight of the complete equipment shall be kept to a minimum commensurate with good engineering design.

S23.10 Power Supply Requirements—The equipment shall be designed to operate with line variations as specified in S27.9 and S27.12. Nominal steady state power supply requirements shall be 115 ± 10 % V at 60 ± 5 % hertz (Hz), single phase, unless otherwise specified in the acquisition requirements.

S23.11 Cable Entrance and Connection—Cable entrance shall be by means of stuffing tubes located on the bottom surface of the enclosure.

S23.12 Operation—The operation of the equipment shall not depend on balancing motor, slide wires, or similar devices. The system shall be completely static. The use of potentiometers are for test and adjustment purposes only.

S23.13 Resistors—Composition type fixed or variable resistors shall not be used.

S23.14 Batteries—Batteries shall not be used.

S23.15 Modular Assemblies—Modular units or assemblies shall be fastened in such a manner to allow for quick and easy removal for maintenance accessibility or replacement.

S23.16 Terminal Boards—The interface with shipboard wiring shall be by means of terminal boards. These terminals shall be accessible with the coverplate removed.

S24. Performance Requirements

Performance tolerances are expressed in percent of equipment span unless stated otherwise.

S24.1 Service Life—Equipment shall be designed for a minimum service life of 40,000 h in a shipboard marine environment.

S24.2 Static Error Band—The static error band shall not exceed plus or minus 1 % (see S27.2).

S24.3 Repeatability—Repeatability of the output shall not exceed 0.3 % (see S27.2).

S24.4 Threshold and Deadband—The maximum least detectable increment plus deadband shall not exceed 0.2 % (see S27.4).

S24.5 Ripple—Equipment output ripple shall not exceed 0.15 % of full scale output (see S27.5).

S24.6 Warm-up Time—The equipment output shall attain a value within plus or minus 1 % of the steady state output with no overshoot in excess of 1 %. Output shall reach this band in 30 min or less and shall remain in this band (see S27.6).
S24.7 Inclination—Maximum deviation of equipment output resulting from inclination shall not exceed 1.0 % (see S27.7).

S24.8 Input Resistance—The equipment output shall remain within the static error band (see S24.2 and S27.8).

S24.9 Supply Voltage and Frequency (Steady State)—Maximum difference between outputs at any voltage and frequency condition and the normal (115 V, 60 Hz) at the same input shall not exceed 1.0 % (see S27.9).

S24.10 Response Time—The 95 % response time shall be 0.5 s or less (see S27.10).

S24.11 Supply Voltage and Frequency (Transients):
- S24.11.1 Voltage—When the equipment is exposed to the limits of specified voltage transient, the equipment output shall remain within ±1 % of the steady state output (see S27.11).
- S24.11.2 Frequency—When the equipment is exposed to the limits of specified frequency transient, the equipment output shall remain within ±1 % of the steady state output (see S27.11).

S24.12 Temperature—When the equipment is exposed to the ambient temperature extremes, performance shall be within the static error band specified in S24.2 (see S27.12).

S24.13 Insulation Resistance—The insulation resistance of the equipment between circuits and between circuits and ground shall be not less than 10 megohms (see S27.13).

S24.14 Vibration—When the equipment is exposed to vibration in accordance with MIL-STD-167-1, monitored output test shall show no variation from steady state output in excess of 2.0 %. There shall be no visible evidence of damage to the equipment as a result of the vibration (see S27.14).

S24.15 Shock—After exposure to shock in accordance with MIL-S-901 but prior to any adjustment, the equipment output shall show no deviation greater than 3 %. A post shock calibration, using adjustments provided, shall conform to performance requirements of S24.2. There shall be no visual evidence of damage to the equipment as a result of the shock (see S27.15).

S25. Workmanship, Finish, and Appearance

S25.1 Cleaning and Surface Finishes—Surfaces of castings, forgings, molded parts, stampings, machined and welded parts shall be free of defects such as cracks, porosity, undercuts, voids and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn-through. There shall be no warpage or dimensional change due to heat from welding operation. There shall be no damage to adjacent parts resulting from welding.

S26. Number of Tests and Retests

S26.1 The number of tests and retests, if any, shall be specified in the acquisition requirements.

S27. Test Methods

S27.1 General Examination and Operation—The unpow-ered temperature monitoring equipment shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, color, finish, workmanship, safety, construction, assembly, dimensions, weight, and marking of identification plates. Examination shall be limited to the examinations that may be performed without disassembling the unit in such a manner that its performance, durability, or appearance would be affected.

S27.2 Static Error Band and Repeatability—Prior to the start of this test, the test sample and associated test equipment shall be energized for a period of 2 h. The test sample shall first be cycled over its full temperature range by slowly increasing and decreasing the input for six continuous cycles. The calibration measurements shall be made at a minimum of 5 equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error band of all calibrations shall meet the requirements of S24.2. Repeatability shall meet the requirements of S24.3.

S27.3 Reference Measurement—A one trial calibration with at least five equally spaced intervals over the entire input range both upscale and downscale shall be conducted when specified in the individual test.

S27.4 Determination of Threshold and Deadband—Threshold and deadband shall be determined with 80 ± 5 % of the temperature span applied to the test sample. The temperature interval beyond this point required to produce a detectable change in output and the temperature interval in the opposite direction to return the output to the original value shall be determined in each direction. Threshold is the first temperature interval. The second temperature interval is the sum of the threshold and deadband. Performance shall conform to the requirements of S24.4.

S27.5 Ripple—equipment Output—Ripple shall be determined at an input of 80 ± 5 % of the temperature span. Performance shall conform to the requirements of S24.5.

S27.6 Warm-up Time—This test shall be conducted to determine the elapsed time between the application of line power to the test sample and the point at which the equipment output reaches the conditions specified in S24.6. The test sample shall be placed in an ambient temperature of 25 ± 2°C (77 ± 3.6°F) for not less than 2 h de-energized. Recording equipment and other auxiliary equipment shall be energized to assure complete warm-up. An input of 80 ± 5 % of the span is to be applied to the test sample and maintained constant during this test. Performance shall conform to S24.6.

S27.7 Inclination—The equipment shall be inclined for a period of at least 1 min in each of the following positions:
1. 45 degrees forward
2. 45 degrees backward
3. 45 degrees to the left
4. 45 degrees to the right

In each position a reference measurement (see S27.3) shall be made. Performance shall conform to S24.7.

S27.8 Input Resistance—For thermocouple sensing technique, a noninductive resistance of 150 ± 1 % Ω shall be placed in each lead to the input terminals to total a circuit resistance of approximately 300 Ω. A reference measurement (see S27.3) shall be made. Performance shall conform to S24.8.
S27.9 **Supply Voltage and Frequency (Steady State)**—The equipment shall be operated at the various combinations of normal, maximum and minimum steady state voltages and frequencies outlined in S24.9. The equipment shall be operated at least 15 min in each combination during which time a reference measurement (see S27.3) shall be taken. Performance shall conform to S24.9.

S27.10 **Response Time**—A step input equal to 10 to 90 % of full scale equipment temperature span shall be applied to the test sample. Performance shall conform to S24.10.

S27.11 **Supply Voltage and Frequency (Transient)**—The tests specified in S27.11.1 through S27.11.2 shall be conducted with a temperature input signal equal to 80 ± 5 % of the input span. Performance shall conform to S24.11.

S27.11.1 **Transient Voltage**—With the equipment operating on the upper limit of steady state voltage, a transient voltage of plus 20 % of nominal voltage recovering to the steady state band in 2 s shall be superimposed. With the equipment operating on the lower limit of steady state voltage, transient voltage of minus 20 % of nominal voltage recovering to the steady state band in 2 s shall be superimposed.

S27.11.2 **Transient Frequency**—With the equipment operating at the nominal frequency, a transient frequency of 2 Hz shall be applied of which not more than 1⁄2 cycle per second is ing at the nominal frequency, a transient frequency of 2 Hz shall be superimposed.

S27.12 **Temperature**—The equipment shall be capable of normal operation (without alignment or adjustment) other than the accessible controls employed for operation of the equipment throughout the following temperature cycle; tolerances in operating characteristics shall be as specified in the individual equipment specification.

1. Hold room temperature at 0 ± 2°C (32 ± 3.6°F) for at least 24 h.
2. Increase room temperature in steps of 10°C (18°F) each, at 30 min per step, until 65 ± 2°C (149 ± 3.6°F) is reached, and hold at that temperature for at least 4 h.
3. Reduce room temperature in steps of 10°C (18°F) each, at 30 min per step, until 25 ± 2°C (77 ± 3.6°F) is reached, and hold at that temperature for at least 4 h. At each temperature plateau 0°C (32°F), 65°C(149°F) and 25°C (77°F), a reference measurement (see S27.3) shall be made. Performance shall conform to S24.12.

S27.13 **Insulation Resistance**—The insulation resistance of the equipment shall be determined by applying 50 V dc between electrical input and output circuits and between these circuits and ground (see S24.13).

S27.14 **Vibration**—The equipment shall be tested in accordance with type I (environmental vibration) of MIL-STD-167-1 except that the upper limit of the frequency range shall be 100 Hz. The amplitudes of vibration shall be in accordance with Table S4. If no resonances are observed, the 2 h endurance test shall be conducted at 100 Hz. During the vibration test, an input equal to 80 ± 5 % of the temperature span shall be applied to the test sample. The output during the test shall be monitored. Performance shall conform to S24.14.

S27.15 **Shock**—The shock test shall be conducted in accordance with MIL-S-901, grade A, class I, type C. During the test an input equal to 80 ± 5 % of the temperature span shall be applied to the equipment. The test sample output during the test shall be monitored. Before and after this test, reference measurements shall be made for comparison (see S27.3). Performance shall conform to S24.15.

**S28. Inspection**

The testing set forth in this specification shall become a part of the manufacturer’s overall inspection system or quality program. The manufacturer’s quality system shall comply with the requirements of ANSI/ASQC 9001-1994, Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing. Certification and registration is highly desired but not required.

S28.1 **Classification of Inspections**—The inspection requirements specified herein are classified as follows:

1. Qualification testing, and
2. Quality conformance testing.

S28.2 **Test Conditions**—Except where the following factors are the variables, the tests shall be conducted with the equipment operating under the following conditions:

1. Ambient temperature shall be 24 ± 5°C (75 ± 9°F),
2. Relative humidity shall be 60 ± 15 %,
3. Supply voltage shall be nominal, and
4. Supply frequency shall be nominal.

S28.3 **Qualification Testing**—The qualification testing shall consist of the tests specified in Table S5. The tests shall be performed in the sequence shown.

S28.3.1 **Sample Size**—The number of samples subjected to qualification tests as specified in Table S5 shall depend on the equipment design. If each range is covered by a separate and distinct design, a sample for each range will require testing. Only one sample of a basically similar design series which may

---

### TABLE S4 Amplitudes of Vibration

<table>
<thead>
<tr>
<th>Frequency Range, (Hz)</th>
<th>Table Amplitude, µm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 20</td>
<td>762 ± 150 (0.030 ± 0.006)</td>
</tr>
<tr>
<td>21 to 50</td>
<td>500 ± 100 (0.020 ± 0.004)</td>
</tr>
<tr>
<td>51 to 100</td>
<td>250 ± 50 (0.010 ± 0.002)</td>
</tr>
</tbody>
</table>

---

### TABLE S5 Qualification Testing

<table>
<thead>
<tr>
<th>Examination and Test</th>
<th>Requirement</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>General examination</td>
<td>—</td>
<td>S27.1</td>
</tr>
<tr>
<td>Output</td>
<td>S24.4</td>
<td>S27.2</td>
</tr>
<tr>
<td>Static error band and repeatability</td>
<td>S24.2</td>
<td>S27.2</td>
</tr>
<tr>
<td>Reference measurement</td>
<td>S24.3</td>
<td>S27.3</td>
</tr>
<tr>
<td>Threshold and deadband</td>
<td>S24.4</td>
<td>S27.4</td>
</tr>
<tr>
<td>Ripple</td>
<td>S24.5</td>
<td>S27.5</td>
</tr>
<tr>
<td>Warm-up time</td>
<td>S24.6</td>
<td>S27.6</td>
</tr>
<tr>
<td>Inclination</td>
<td>S24.7</td>
<td>S27.7</td>
</tr>
<tr>
<td>Input resistance</td>
<td>S24.8</td>
<td>S27.8</td>
</tr>
<tr>
<td>Supply line voltage and frequency, steady-state</td>
<td>S24.9</td>
<td>S27.9</td>
</tr>
<tr>
<td>Response time</td>
<td>S24.10</td>
<td>S27.10</td>
</tr>
<tr>
<td>Supply line voltage and frequency, transients</td>
<td>S24.11</td>
<td>S27.11</td>
</tr>
<tr>
<td>Temperature</td>
<td>S24.12</td>
<td>S27.12</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S24.13</td>
<td>S27.13</td>
</tr>
<tr>
<td>Vibration</td>
<td>S24.14</td>
<td>S27.14</td>
</tr>
<tr>
<td>Shock</td>
<td>S24.15</td>
<td>S27.15</td>
</tr>
</tbody>
</table>
cover many ranges need be tested if mechanical and electrical similarity is deemed sufficient by the purchaser.

S28.4 Quality Conformance Testing—All temperature measurement equipment offered for delivery shall be subjected to the examination and tests listed in Table S6 and shall be conducted in the order listed. Failure of any temperature equipment to meet the requirements of this specification shall be cause for rejection.

S29. Certification

S29.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test result shall be furnished. It is recommended that all test data remain on file for three years at the manufacturer’s facility for review by purchaser upon request.

TABLE S6 Quality Conformance Testing

<table>
<thead>
<tr>
<th>Examination and Test</th>
<th>Requirement</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>General examination</td>
<td>---</td>
<td>S27.1</td>
</tr>
<tr>
<td>Output</td>
<td>S24.4</td>
<td>S27.2</td>
</tr>
<tr>
<td>Static error band and repeatability</td>
<td>S24.2</td>
<td>S27.2</td>
</tr>
<tr>
<td>Ripple</td>
<td>S24.5</td>
<td>S27.5</td>
</tr>
<tr>
<td>Input resistance (thermocouple sensing</td>
<td>S24.8</td>
<td>S27.8</td>
</tr>
<tr>
<td>technique only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S24.13</td>
<td>S27.13</td>
</tr>
</tbody>
</table>

S30. Product Marking

S30.1 Product marking requirements shall be specified in the acquisition requirements but at a minimum, shall include:

1. Manufacturer’s name,
2. Classification, and

S31. Packaging and Package Marking

S31.1 Packaging and package marking shall be in accordance with Section 15.

THERMOCOUPLE AND RESISTANCE TEMPERATURE DETECTOR ASSEMBLIES (NAVAL SHIPBOARD USE)

The following appendix to supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard (ASTM F 2362) and this supplement’s appendix, the requirements of this supplement’s appendix shall take precedence for equipment acquired by this supplement’s appendix. This document supersedes MIL-T-24388, Thermocouple and Resistance Temperature Detector Assemblies, General Specification for (Naval Shipboard), for new ship construction.

S32. Scope

S32.1 This specification covers environmentally hardened resistance thermometers and thermocouple sensors that transform the surrounding thermal energy in a manner that can be electrically measured and converted to a temperature using a signal conditioner/temperature monitor. Types of configurations covered in this specification are those which place the resistance thermometer or thermocouple sensor directly into the medium (bare bulb), into a thermowell, or embedded into a bearing.

S32.2 Resistance thermometers and thermocouple sensors are intended to convert temperature measured to an electrical output for input to a temperature signal conditioner.

S32.3 The U.S. Government preferred system of measurement is the metric SI system. However, since this item was originally designed using inch-pound units of measurement, in the event of conflict between the metric and inch-pound units, the inch-pound units shall take precedence.

S33. Referenced Documents

S33.1 Commercial Documents:
S33.1.1 ASTM Standards:7

7 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

A 249 Specification for Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes
A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service (DOD adopted)
A 276 Specification for Stainless and Heat-Resisting Steel Bars and Shapes (DOD adopted)
A 312 Specification for Seamless and Welded Austenitic Stainless Steel Pipe (DOD adopted)
B 23 Specification for White Metal Bearing Alloys Known Commercially as “Babbitt Metal”
B 117 Method of Salt Spray (Fog) Testing (DOD adopted)
B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar (DOD adopted)
B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire (DOD adopted)
B 355 Specification for Nickel-Coated Soft or Annealed Copper Wire (DOD adopted)
B 637 Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High Temperature Service
D 1457 Specification for Polytetrafluoroethylene PTFE Molding and Extrusion Materials (DOD adopted)
E 344 Terminology Relating to Thermometry and Hydrometry
S34. Terminology

S34.1 Definitions—Definitions and terminology shall be in accordance with Terminology E 344.

S35. Classification

S35.1 Design Type—Resistance thermometers and thermocouple sensors shall be classified according to the following variables:

Example: ASTM F2362S32-KTC-TW-S7

<table>
<thead>
<tr>
<th>Specification Type</th>
<th>Configuration Type</th>
<th>Designation Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2362S32</td>
<td>(see S35.2)</td>
<td>S7</td>
</tr>
<tr>
<td></td>
<td>TW</td>
<td>(see S35.4)</td>
</tr>
</tbody>
</table>

S35.2 Type—The type of resistance thermometer or thermocouple sensor shall be designated by one of the following three-letter symbols:

Type

- Type K thermocouple sensor
- Resistance thermometer with nickel element
- Resistance thermometer with platinum element

Symbols

- KTC
- NRT
- PRT

S35.3 Configuration—Type of configuration for which the resistance thermometer or thermocouple sensor is intended shall be designated by one of the following two-letter symbols:

<table>
<thead>
<tr>
<th>Type of Configuration</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermowell</td>
<td>TW</td>
</tr>
<tr>
<td>Bare bulb</td>
<td>BB</td>
</tr>
<tr>
<td>Embedded</td>
<td>EM</td>
</tr>
</tbody>
</table>

S35.4 Designation Number—The designation number used to specify the sheath length and other applicable parameters within each type of configuration shall be denoted by one or two numerals or by one or two numerals preceded by a letter found in one of the following:

<table>
<thead>
<tr>
<th>Type of Configuration</th>
<th>Table Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW</td>
<td>S7</td>
</tr>
<tr>
<td>BB</td>
<td>S8</td>
</tr>
<tr>
<td>EM</td>
<td>S9</td>
</tr>
</tbody>
</table>

S36. Ordering Information

S36.1 The purchaser shall provide the manufacturer with all of the pertinent application data shown in accordance with S36.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S36.2 Acquisition Requirements—Acquisition documents should specify the following:

1. Title, number, and date of this specification,
2. Classification required,
3. Design type,
4. Range,
5. Quantity required,
6. When qualification testing is required,
7. Disposition of qualification test samples,
8. Product marking requirements, and
9. Packaging requirements.

S37. Materials and Manufacture

S37.1 Materials—Recommended materials of resistance thermometer and thermocouple sensor components are provided in Table S7.

S37.1.1 Nonmetallic Materials—Nonmetals, when used for seals, protective finishes, and so forth, shall be moisture and flame resistant, shall not support fungus growth, and shall not be adversely affected by the ambient environments specified in the performance requirements of this specification.

S37.1.2 Connecting Wire and End Closure—The connecting wire and end closure shall be airtight, nonhygroscopic, fungus resistant, flame resistant, and able to form a chemical bond with connecting wires (thermowell configuration), electrical connector receptacle pins, (bare bulb configuration), or the connecting wire insulation (embedded configuration) and with the sheath sufficient to meet the sealing requirements. The connecting wire end closure shall not chemically react, degrade, or outgas when subjected to the following: air, distilled water, sea water, salt, petroleum and silicone based oils, oil solvents, prolonged (greater than 1 month) periods of exposure to ambient temperatures, prolonged periods of exposure to elevated temperatures up to 205°C (400°F), and exposure to prolonged cycling periods from ambient to elevated temperatures. A connecting wire and enclosure consisting of a ceramic-to-metal or a glass-to-metal seal shall also incorporate other characteristics to make it impenetrable to fluids and shall be considered a hermetic seal. The connecting wire end closure shall meet all the performance requirements specified in S39, including the connecting wire end closing requirement (see S42.8).
S37.1.3 **Fungus-inert Materials**—Materials which provide a nutrient medium for fungus and insects shall not be used in the construction of any resistance thermometer or thermocouple sensor.

S37.1.4 **Restricted Materials**—Cadmium or cadmium-plated parts shall not be used.

### S38. Physical Properties

**S38.1 Construction**—Resistance thermometers and thermocouple sensors are shown on Figs. S1-S6. Resistance thermometer and thermocouple sensor construction dimensions and application temperatures for thermowell, bare bulb, and embedded configurations shall be in accordance with Table S8, Table S9, and Table S10 respectively.

**S38.1.1 Resistance Thermometer**—Resistance thermometers have the following characteristics:

1. The two resistance thermometer elements have different temperature ranges (excluding the EM configuration):
   - Nickel: -40 to 205°C (-40 to 400°F)
   - Platinum: -40 to 538°C (-40 to 1000°F)
2. High accuracy,
3. Excellent stability and reproducibility but slow in response,
4. Easily interchangeable but damages easily if not handled properly. Can be matched to close tolerances for temperature difference measurements, and
5. Resistance thermometers with platinum elements should be specified for new construction and new instrument installations. Resistance thermometers with nickel elements should be restricted to retrofit and replacements only.

**S38.1.2 Thermocouple Sensors**—Thermocouple sensors have the following characteristics:

1. Simple construction,
2. Small signal output is produced which requires sensitive measuring instruments,
3. Lower cost and faster response than the resistance thermometer,
4. Type K thermocouple covers a temperature range of -40 to 816°C (-40 to 1500°F) (excluding EM configuration),
5. Compensation for reference junction temperature is required,
6. Attains high accuracy but subject to changes within the accuracy limit with use. These changes become more pronounced as the temperature increases.

---

**TABLE S7 Materials**

<table>
<thead>
<tr>
<th>Part</th>
<th>Configuration</th>
<th>Material</th>
<th>Material Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babbitt topping</td>
<td>EM</td>
<td>Babbitt</td>
<td>ASTM B 23, grade 2</td>
<td></td>
</tr>
<tr>
<td>Connecting wire resistance</td>
<td>TW</td>
<td>22 AWG, stranded nickel-plated</td>
<td>MIL-W-16878 and MIL-W-16878/25</td>
<td></td>
</tr>
<tr>
<td>thermometer</td>
<td>BB</td>
<td>copper</td>
<td>ASTM D 1457</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EM</td>
<td>24 AWG, stranded nickel-plated</td>
<td>MIL-W-81381 and MIL-W-81381/12</td>
<td>Conductors IAW MIL-W-5846</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or silver-plated copper</td>
<td>MIL-W-81381/12 or MIL-W-16878</td>
<td>and no plating</td>
</tr>
<tr>
<td>Connecting wire thermocouple</td>
<td>TW</td>
<td>22 AWG, type K</td>
<td>MIL-W-5846</td>
<td></td>
</tr>
<tr>
<td>sensor</td>
<td>BB</td>
<td>PTFE insulated</td>
<td>ASTM D 1457</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EM</td>
<td>24 AWG, type K fluorocarbon/</td>
<td>MIL-W-81381/12 or MIL-W-81381/12</td>
<td>Conductors IAW MIL-W-5846</td>
</tr>
<tr>
<td></td>
<td></td>
<td>polymide insulated</td>
<td>and no plating</td>
<td></td>
</tr>
<tr>
<td>Connection head cap</td>
<td>TW</td>
<td>Aluminum 365751</td>
<td>MIL-A-8626, type 1; 356 T6</td>
<td></td>
</tr>
<tr>
<td>Connection head extension</td>
<td>TW</td>
<td>304 SST</td>
<td>ASTM A 312</td>
<td>Clear anodized</td>
</tr>
<tr>
<td>Connection head</td>
<td>TW</td>
<td>304 SST</td>
<td>MIL-A-8626, type 1; 356 T6</td>
<td></td>
</tr>
<tr>
<td>Identification plate</td>
<td>BB</td>
<td>302 set</td>
<td>MIL-P-15024</td>
<td></td>
</tr>
<tr>
<td>Gasket</td>
<td>BB</td>
<td>Copper</td>
<td>ASTM B 152</td>
<td>Tempar 0</td>
</tr>
<tr>
<td>Pins, connector</td>
<td>BB:PRT</td>
<td>Nickel-plated copper</td>
<td>MS 3102R-145-7S</td>
<td>Receptacle</td>
</tr>
<tr>
<td>Receptacle plug</td>
<td>BB:KTC</td>
<td>Nickel-plated copper</td>
<td>MS 3102-145-7P</td>
<td>Plug</td>
</tr>
<tr>
<td>Seal, ceramic to metal wire</td>
<td>BB</td>
<td>Glass to metal epoxy</td>
<td>MS 3106F-12S-3S</td>
<td></td>
</tr>
<tr>
<td>end enclosure</td>
<td>EM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheath</td>
<td>TW</td>
<td>316 SST</td>
<td>ASTM A 249</td>
<td>Required for type KTC</td>
</tr>
<tr>
<td></td>
<td>BB</td>
<td>UNS NO4405</td>
<td>ASTM A 269</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EM</td>
<td>99 % pure copper</td>
<td>ASTM B 167</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 % not restricted</td>
<td></td>
</tr>
<tr>
<td>Sheath, internal insulation</td>
<td>BB, TW:</td>
<td>Aluminum Oxide or</td>
<td>Chemical certification on file</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NRT,KTC:</td>
<td>Magnesium Oxide</td>
<td>required</td>
<td></td>
</tr>
<tr>
<td>Spring, compression</td>
<td>TW</td>
<td>Inconel</td>
<td>ASTM B 637</td>
<td></td>
</tr>
<tr>
<td>Spring stop</td>
<td>TW</td>
<td>300 Series SST</td>
<td>ASTM A 249</td>
<td></td>
</tr>
<tr>
<td>Threaded fasteners</td>
<td>TW</td>
<td>Corrosion-resistant steel</td>
<td>ASTM A 276</td>
<td>(1)</td>
</tr>
<tr>
<td>Washers</td>
<td>TW</td>
<td>316 SST</td>
<td>ASTM A 276</td>
<td></td>
</tr>
</tbody>
</table>
Preferable for use with thermowells having a 5.08 cm (2 in.) immersion depth since the thermocouple sensor’s minimum immersion depth is significantly smaller than that of a resistance thermometer, and

Note—Dimensions and tolerances are reference only to meet installation requirements.

**FIG. S1 Resistance Thermometer/Thermocouple Sensor Construction**

(1) Dimension to suit particular head design.

(2) Inside diameter shall be sized to allow clearance for sensor sheath, spring stop, and spring.

(3) Minimum wall thickness shall be 0.109 in..

**FIG. S2 Connection Head Extension**

(7) Preferable for use with thermowells having a 5.08 cm (2 in.) immersion depth since the thermocouple sensor’s minimum immersion depth is significantly smaller than that of a resistance thermometer, and
Preferable for use in the EM configuration since extremely fine resistance thermometer element wire is very susceptible to electrical opens, shorts, or intermittent behavior in service.

S38.2 New Construction—Resistance thermometers with platinum elements should be specified for new construction and new instrument installations with the following exceptions:

(1) Thermowells have a 5.08 cm (2 in.) immersion depth, see S38.1.2(7), and

(2) EM configuration installations, see S38.1.2(8).

S38.2.1 Resistance Thermometer Element:

S38.2.1.1 Location—The resistance thermometer element shall be located within the bottom 2 in. of sheath for the thermowell and bare bulb configurations. The resistance thermometer element for all configurations shall be located in a manner such that the installation resistance test requirements are met.

S38.2.1.2 Resistance Thermometer Current—Resistance thermometers shall withstand a continuous operating current of 6 milliamperes (mA) direct current (dc).

S38.2.1.3 Temperature versus Resistance—Relationships for resistance thermometers shall be in accordance with Table S11 and Table S12 with limits of error specified in S39.2.

S38.2.2 Thermocouple:

S38.2.2.1 Location—The thermocouple measuring junction shall be ungrounded and located within the bottom 6.35 mm (¼ in.) of the sheath for the thermowell and bare bulb configurations. The thermocouple measuring junction shall be
S38.2.2 Connecting Wires—The diameter of the connecting wire shall be the AWG as specified in Table S7. The connecting wire material shall also be in accordance with Table S7.

S38.2.3 Resistance Thermometers:
S38.2.3.1 External Insulation (TW and EM Configurations)—The material for the external insulation shall be specified in Table S7.
S38.2.3.2 Color Code—The external insulation for the single connecting wire attached to one end of the resistance ungrounded and located in the middle of the sheath for the embedded configuration.
thermometer element shall be color coded red. The external insulation for the two connecting wires attached to the other end of the resistance thermometer element shall be color coded white or amber.

S38.2.3.3 Internal Insulation (TW and BB Configurations)—The resistance thermometer connecting wires shall be insulated from the sheath and from each other by alumina (A12O3). The alumina shall be alpha alumina with a minimum content of 99.5% alumina. Sulfur shall not exceed 50 parts per million (ppm) while carbon shall not exceed 200 ppm.

S38.2.3.4 Number of Connecting Wires—The resistance thermometers shall be of three-wire construction except for the bare bulb configuration with a nickel element which shall be of two-wire construction.

S38.2.4 Thermocouple Sensors:
S38.2.4.1 External Insulating (TW and EM Configurations)—The material for external insulation shall be as specified in Table S7.
S38.2.4.2 Color Code—The external insulation for the positive (chromel) connecting wire shall be yellow. The external insulation for the negative (alumel) connecting wire shall be red.

FIG. S5 Bare Bulb Type Resistance Thermometer/Thermocouple

S38.2.4.3 Internal Insulation (TW and EM Configurations)—The thermocouple sensor connecting wires shall be insulated from each other, except at the measuring junction, and from the sheath by magnesia (MgO). The magnesia shall be electrically fused with a 96.5% minimum content of magnesia. The sulfur content shall be less than 50 ppm and the carbon content less than 200 ppm.

S38.2.5 Thermowell Configuration:
S38.2.5.1 Temperature Exposures—Maximum connecting head temperature shall be 300°F for resistance thermometers with nickel elements, 260°C (500°F) for resistance thermometers with platinum elements, and 260°C (500°F) for type K thermocouple sensors.
S38.2.5.2 Watertight Enclosure—Resistance thermometers and thermocouple sensors shall be watertight such that water directed at the sensor from any angle is prevented from entry.
S38.2.5.3 Construction—Thermowell configuration shall consist of resistance thermometer or thermocouple sensor, construction head, and a connection head extension as shown of Figs. S1-S4.
S38.2.5.4 Connection Head Cap—The connection head of the thermowell configuration shall be provided with a screw-on type cap with metal link chain.
S38.2.5.5 Terminal Board—Terminal board shall be secured to the connection head.

S38.2.5.6 Thermowells—When resistance thermometers and thermocouple sensors are intended for use with thermowells, the thermowells shall be in accordance with ASME B40.9, Supplement 1.

S38.2.6 Bare Bulb Configuration:

S38.2.6.1 Temperature Exposures—The maximum connector receptacle and plug temperature shall be 149°C (300°F).

S38.2.6.2 Watertight Enclosure—Resistance thermometers and thermocouple sensors shall be watertight such that water directed at the sensor from any angle is prevented from entry.

S38.2.6.3 Construction—The bare bulb configuration shall be of one-piece construction as shown on Fig. S5.

S38.2.6.4 End Cap—The connector receptacle shall be provided with a screw-on end cap.

S38.2.6.5 Pressure Requirements—The resistance thermometer and thermocouple sensor shall withstand 37.9 MPa (5500 psi) when inserted into air stream at a temperature of 182°C (360°F) with velocity of 12.2 m (40 ft) per second.

S38.2.7 Embedded Configuration:

S38.2.7.1 Temperature Exposures—Resistance thermometers and thermocouple sensors shall withstand a maximum temperature of 205°C (400°F) for continuous use, 274°C (525°F) for short term exposure of 15 min, and 288°C (550°F) for short term exposure of 2 min.

S38.2.7.2 Construction—The embedded configuration shall consist of the resistance thermometer or thermocouple sensor as shown in Fig. S6.

S38.2.7.3 Scoring—The material and construction of the resistance thermometer or thermocouple sensor shall be such that in the event the bearing should fail and be wiped to a depth of 2.54 ± 254 μm (0.10 ± 0.01 in.) over the area of the resistance thermometer or thermocouple sensor, scoring of a carbon steel shaft having a Brinell hardness of 170 to 180 will be limited to a depth of 7.62 μm (300 μin.) or less.

S38.2.7.4 Babbitt Topping—The tip of the sheath shall contain a 2.54 ± 1.5 mm (0.10 ± 0.06 in.) thick topping of babbitt. The diameter, including maximum to tolerance, of the babbitt topping shall conform to the diameter of the sheath.

S38.2.8 Cleaning and Surface Finishes—Surface of castings, forgings, molded parts, stampings, machined and welded parts shall be free of defects such as cracks, porosity, undercuts, voids, and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surface shall be smooth and edges shall be either rounded or beveled. There shall be no burn-through. There shall be no warpage or dimensional change due to heat from welding operation. There shall be no damage to adjacent parts resulting from the welding.

S39. Performance Requirements

S39.1 Insulation Resistance—The insulation resistance shall be determined at 50 VDC and shall be no less than 10 megohms.

S39.2 Accuracy—The span and limits of error shall be as specified in Table S13 (see S42.2).

S39.2.1 Accuracy Repeatability—The span and limits of error shall be as specified in Table S14.

S39.2.2 Reference Measurement—The performance shall conform to S39.2 (see S42.2.2).

S39.3 Response Time—Response time of the resistance thermometers and thermocouple sensors shall be as follows:

(1) 8 s or less for thermowell configuration,
**TABLE S8 Construction Dimensions and Application Temperatures, Thermowell Configuration**

<table>
<thead>
<tr>
<th>Type</th>
<th>Designation</th>
<th>Insertion Length, cm (in.)</th>
<th>Dimensions, cm (in.) (see Fig. S1, Fig. S2, and Fig. S4)</th>
<th>Temperature Range, °C (°F)ᵃ</th>
<th>Maximum Connection Head Temp, °C (°F)</th>
<th>Thermowell Design Number (B40.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRT</td>
<td>4</td>
<td>6.8</td>
<td>L ± 0.1 mm (±0.04)</td>
<td>A ± 0.75 mm (±0.03)</td>
<td>9.53</td>
<td>13.34</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.8</td>
<td>(2.69) (4.44) (1.75)</td>
<td>(3.75) (5.25)</td>
<td>-40 to 600</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>11.66</td>
<td>(2.69) (6.69) (4.00)</td>
<td>(6.00) (7.50)</td>
<td>-40 to 538</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>11.91</td>
<td>(4.69) (8.69) (4.00)</td>
<td>(8.00) (9.50)</td>
<td>-40 to 538</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>11.91</td>
<td>(4.69) (8.69) (4.00)</td>
<td>(8.00) (9.50)</td>
<td>-40 to 538</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>16.99</td>
<td>(6.69) (8.69) (2.00)</td>
<td>(9.50) (9.50)</td>
<td>-40 to 538</td>
<td>260</td>
</tr>
<tr>
<td>NRT</td>
<td>9</td>
<td>6.8</td>
<td>(2.69) (9.69) (7.00)</td>
<td>(9.00) (10.50)</td>
<td>-40 to 205</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>11.66</td>
<td>(4.59) (10.19) (5.60)</td>
<td>(9.50) (11.00)</td>
<td>-40 to 205</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>11.91</td>
<td>(4.69) (11.69) (7.00)</td>
<td>(11.00) (12.50)</td>
<td>-40 to 205</td>
<td>149</td>
</tr>
<tr>
<td>KTC</td>
<td>4</td>
<td>6.8</td>
<td>(2.69) (4.44) (1.75)</td>
<td>(3.75) (5.25)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.8</td>
<td>(2.69) (4.44) (1.75)</td>
<td>(3.75) (5.25)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>21.26</td>
<td>(6.69) (8.69) (4.00)</td>
<td>(8.00) (9.50)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>11.91</td>
<td>(2.69) (6.69) (4.00)</td>
<td>(8.00) (9.50)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>11.66</td>
<td>(4.59) (10.19) (5.60)</td>
<td>(9.50) (11.00)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>11.91</td>
<td>(4.69) (11.69) (7.00)</td>
<td>(11.00) (12.50)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>31.45</td>
<td>(18.38) (1.75)</td>
<td>(17.69) (19.19)</td>
<td>-40 to 316</td>
<td>260</td>
</tr>
</tbody>
</table>

ᵃ For 'A' dimensions less than 12.7 cm (5.0 in.) the temperature range is limited to 56°C (130°F) above the maximum connection head temperature.
ᵇ Reference dimension only. Y and Z as required to meet installation requirements.

**TABLE S9 Construction Dimensions and Application Temperatures, Bare Bulb Configuration**

<table>
<thead>
<tr>
<th>Type</th>
<th>Designation</th>
<th>Size, cm (in.) (see Fig. S5)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRT</td>
<td>B1</td>
<td>5.71 (2.25)</td>
<td>8.89 (3.50)</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>16.5 (6.50)</td>
<td>19.69 (7.75)</td>
</tr>
<tr>
<td>PRT</td>
<td>B3</td>
<td>5.71 (2.25)</td>
<td>8.89 (3.50)</td>
</tr>
<tr>
<td></td>
<td>B4</td>
<td>16.5 (6.50)</td>
<td>19.69 (7.75)</td>
</tr>
<tr>
<td>KTC</td>
<td>B5</td>
<td>5.71 (2.25)</td>
<td>8.89 (3.50)</td>
</tr>
<tr>
<td></td>
<td>B6</td>
<td>16.5 (6.50)</td>
<td>19.69 (7.75)</td>
</tr>
</tbody>
</table>

**TABLE S10 Construction Dimensions and Application Temperatures, Embedded Configuration**

<table>
<thead>
<tr>
<th>Type</th>
<th>Designation</th>
<th>Temperature Range, °C (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRT</td>
<td>E1</td>
<td>-40 to 205 (-40 to 400)</td>
</tr>
<tr>
<td>PRT</td>
<td>E2</td>
<td>-40 to 205 (-40 to 400)</td>
</tr>
<tr>
<td>KTC</td>
<td>E3</td>
<td>-40 to 205 (-40 to 400)</td>
</tr>
</tbody>
</table>

(2) 15 s or less for bare bulb configuration, and
(3) 5 s or less for embedded configuration.

**S39.4 Self-heating (Resistance Thermometers only)**—The temperature change due to self heating of the resistance thermometers shall not exceed 0.6°C (1.1°F) at an input power level of 5 milliwatts (see S42.4).

**S39.5 Thermal Cycling**—When subjected to 1500 thermal cycles, there shall be no shorts, opens, or evidence of intermittent behavior. The reference thermometers and the thermocouple sensors shall show no evidence of physical damage as result of thermal cycling. The reference measurement performed at the conclusion of the thermal cycling shall conform to S39.2.

**S39.6 Over-temperature (EM Configuration)**—Resistance thermometers and thermocouple sensors shall conform to the temperature span and accuracy requirements specified in S39.2 after being subjected to over-temperature. During over-temperature, there shall be no shorts, opens, or evidence of intermittent behavior. The reference measurement performed at the conclusion of over-temperature shall conform to S39.2 (see S42.5).

**S39.7 Terminal Strength (TW and EM Configurations)**—Attachment of connecting wires to the connecting wire end closure and their encapsulation into the sheath shall withstand the specified static load. The resistance thermometers and thermocouple sensors shall be axially loaded for 15 min without causing circuit failure or loss of watertight integrity.
shall be no observed evidence of air bubbles while under vacuum or pressure, there shall be no physical damage to the sensors. After application of vacuum and pressure, the performance of the resistance thermometers and thermocouple sensors shall conform to S39.1 and S39.2 (see S42.8).

S39.9 Enclosure (TW and BB configurations)—There shall be no leakage of water into the watertight enclosure (see S42.9).

S39.10 Salt Spray—Resistance thermometers and thermocouple sensors shall show no appreciable corrosion or other damage when subjected to salt spray (S42.10). The performance of the resistance thermometers and thermocouple sensors shall conform to S39.1 and S39.2.

S39.11 Spring Loading (TW Configuration)—When compressed 7.62 cm (3/16 in.), the spring shall exert a minimum force of 2.27 kg (5 lb) (S42.11).

S39.12 Vibration—When exposed to vibration per MIL-STD-167-1, the resistance thermometers and thermocouple sensors shall show no evidence of improper operation, failure, or damage (see S42.12). The electrical signal from the resistance thermometer and thermocouple sensor shall be monitored during vibration and there shall be no shift in the temperature indication. A reference measurement performed at the conclusion of vibration shall meet the specified accuracy requirements of S39.2.

S39.13 Shock—Resistance thermometers and thermocouple sensors shall withstand the effects of shock in accordance with MIL-S-901 (S42.13). A reference measurement performed after exposure to shock shall meet the specified accuracy requirements of S39.2.

### Table S11 Temperature versus Resistance Characteristics for Resistance Thermometers with Nickel Elements

<table>
<thead>
<tr>
<th>Temperature °C (°F)</th>
<th>Resistance (Ohms)</th>
<th>Temperature °C (°F)</th>
<th>Resistance (Ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40.0 (-40)</td>
<td>92.75</td>
<td>21.1 (70)</td>
<td>135.46</td>
</tr>
<tr>
<td>-34.4 (-30)</td>
<td>96.39</td>
<td>26.7 (80)</td>
<td>139.66</td>
</tr>
<tr>
<td>-28.9 (-20)</td>
<td>100.07</td>
<td>32.2 (90)</td>
<td>143.92</td>
</tr>
<tr>
<td>-23.3 (-10)</td>
<td>103.80</td>
<td>37.8 (100)</td>
<td>148.24</td>
</tr>
<tr>
<td>-17.8 (0)</td>
<td>107.57</td>
<td>43.3 (110)</td>
<td>152.61</td>
</tr>
<tr>
<td>-12.2 (10)</td>
<td>111.40</td>
<td>48.9 (120)</td>
<td>157.04</td>
</tr>
<tr>
<td>-6.7 (20)</td>
<td>115.28</td>
<td>54.4 (130)</td>
<td>161.54</td>
</tr>
<tr>
<td>-1.3 (30)</td>
<td>119.21</td>
<td>60.0 (140)</td>
<td>166.09</td>
</tr>
<tr>
<td>0.0 (32)</td>
<td>120.00</td>
<td>65.6 (150)</td>
<td>170.71</td>
</tr>
<tr>
<td>4.4 (40)</td>
<td>123.19</td>
<td>71.1 (160)</td>
<td>175.39</td>
</tr>
<tr>
<td>10.0 (50)</td>
<td>127.23</td>
<td>76.7 (170)</td>
<td>180.13</td>
</tr>
<tr>
<td>15.6 (60)</td>
<td>131.32</td>
<td>82.2 (180)</td>
<td>184.94</td>
</tr>
</tbody>
</table>

#### Note—Resistance thermometers with nickel elements shall not be used for temperature applications above 400°F.

### Table S12 Temperature versus Resistance Characteristics for Resistance Thermometers with Platinum Elements

<table>
<thead>
<tr>
<th>Temperature °C (°F)</th>
<th>Resistance (Ohms)</th>
<th>Temperature °C (°F)</th>
<th>Resistance (Ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40.0 (-40)</td>
<td>83.97</td>
<td>100.0 (212)</td>
<td>139.24</td>
</tr>
<tr>
<td>-28.9 (-20)</td>
<td>88.44</td>
<td>104.4 (220)</td>
<td>140.96</td>
</tr>
<tr>
<td>-17.8 (0)</td>
<td>92.90</td>
<td>108.7 (226)</td>
<td>149.51</td>
</tr>
<tr>
<td>-6.7 (20)</td>
<td>97.34</td>
<td>114.8 (230)</td>
<td>153.76</td>
</tr>
<tr>
<td>0.0 (32)</td>
<td>100.00</td>
<td>120.9 (240)</td>
<td>158.00</td>
</tr>
<tr>
<td>4.4 (40)</td>
<td>101.77</td>
<td>127.0 (250)</td>
<td>162.22</td>
</tr>
<tr>
<td>15.6 (60)</td>
<td>106.18</td>
<td>131.1 (260)</td>
<td>166.43</td>
</tr>
<tr>
<td>27.6 (80)</td>
<td>110.58</td>
<td>135.2 (266)</td>
<td>170.63</td>
</tr>
<tr>
<td>37.8 (100)</td>
<td>114.96</td>
<td>140.3 (280)</td>
<td>174.81</td>
</tr>
<tr>
<td>48.9 (120)</td>
<td>119.33</td>
<td>145.4 (290)</td>
<td>179.17</td>
</tr>
<tr>
<td>60.0 (140)</td>
<td>123.69</td>
<td>150.6 (300)</td>
<td>183.12</td>
</tr>
<tr>
<td>71.1 (160)</td>
<td>128.03</td>
<td>155.8 (310)</td>
<td>187.26</td>
</tr>
<tr>
<td>82.2 (180)</td>
<td>132.35</td>
<td>161.0 (320)</td>
<td>191.38</td>
</tr>
<tr>
<td>93.3 (200)</td>
<td>136.67</td>
<td>166.2 (330)</td>
<td>195.49</td>
</tr>
</tbody>
</table>

### Table S13 Accuracy (Span of Limits of Error)

<table>
<thead>
<tr>
<th>Temperature °C (°F)</th>
<th>Resistance (Ohms)</th>
<th>Temperature °C (°F)</th>
<th>Resistance (Ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.6°C (1°F)</td>
<td>1.1°C (2°F)</td>
<td>3.0°C (5°F)</td>
<td>5.0°C (10°F)</td>
</tr>
<tr>
<td>82.2 (180)</td>
<td>132.35</td>
<td>161.0 (320)</td>
<td>191.38</td>
</tr>
<tr>
<td>93.3 (200)</td>
<td>136.67</td>
<td>166.2 (330)</td>
<td>195.49</td>
</tr>
</tbody>
</table>

### Table S14 Accuracy Repeatability (Span of Limits of Error)

<table>
<thead>
<tr>
<th>Temperature Range °C (°F)</th>
<th>Limits of Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.6°C (1°F)</td>
<td>±0.6°C (1°F)</td>
</tr>
<tr>
<td>0.0°C (32°F)</td>
<td>±0.5°C (1°F)</td>
</tr>
<tr>
<td>4.4°C (40°F)</td>
<td>±0.4°C (1°F)</td>
</tr>
<tr>
<td>15.6°C (60°F)</td>
<td>±0.3°C (1°F)</td>
</tr>
</tbody>
</table>

(see S42.7). The reference measurement performed at the conclusion of static loading shall conform to S39.2.

S39.8 Connecting Wire and Closure—When subjected to a vacuum or pressure, there shall be no physical damage to the resistance thermometers and thermocouple sensors and there shall be no observed evidence of air bubbles while under vacuum. After application of vacuum and pressure, the performance of the resistance thermometers and thermocouple sensors shall conform to S39.1 and S39.2 (see S42.8).
S39.14 Pressure (EM Configuration)—The embedded resistance thermometers and thermocouple sensors shall not deform to such a degree that the babbitt surface is visually determined to be dimpled, cracked, or ruptured after exposure to a pressure of 12.4 MPa (1800 lb/in.²) gauge. The insulation resistance between each connecting wire and the babbitt surface shall be no less than 10 megohms when measured both before and at the conclusion of exposure to pressure. The resistance thermometers and thermocouple sensors shall meet the reference measurement requirements of S39.2 both before and at the conclusion of exposure to pressure (S42.14).

S39.15 Scoring (EM Configuration)—The stylus traces resulting from the application of a scoring force of 3.63 kg (8 lb) shall not indicate a scoring depth exceeding 7.62 micrometers (300 microinches) (S42.15).

S40. Workmanship, Finish, and Appearance

S40.1 Cleaning and Surface Finishes—Surfaces of castings, forgings, molded parts, stampings, and welded parts shall be free of defects such as cracks, porosity, undercuts, voids and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn-through. There shall be no warpage or dimensional change due to heat from welding operation. There shall be no damage to adjacent parts resulting from welding.

S41. Number of Tests and Retests

S41.1 The number of tests and retests, if any, shall be specified in the acquisition requirements.

S42. Test Methods

S42.1 Insulation Resistance—Insulation resistance shall be determined by applying 50 V (dc) between the connecting wires and the sheath. Performance shall conform to S39.1.

S42.2 Accuracy—Resistance thermometers and thermocouple sensors shall be calibrated in accordance with the requirements of S39.2. The temperature of the bath fluid shall be as shown in Table S15, ±2.8°C (5°F), with a temperature gradient of ±0.06°C (½°F) for salt bath, under steady state temperature conditions. The resistance thermometers and thermocouple sensors shall be calibrated at temperatures listed in the increasing order. Performance shall conform to S39.2.

S42.2.1 Accuracy Repeatability—The accuracy test specified in S42.2 shall be performed two additional times. Performance shall conform to S39.2.1.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Type</th>
<th>Temperature Range, (°C)</th>
<th>Calibration Values, (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW, BB</td>
<td>NRT</td>
<td>-40 to 205</td>
<td>-29, 0, 27, 82, 138, 193</td>
</tr>
<tr>
<td></td>
<td>PRT</td>
<td>-40 to 538</td>
<td>-29, 0, 93, 205, 316, 427, 527</td>
</tr>
<tr>
<td></td>
<td>KTC</td>
<td>-40 to 1500</td>
<td>-20, 32°, 200°, 400, 600°, 800, 980°</td>
</tr>
<tr>
<td></td>
<td>EM</td>
<td>-40 to 181</td>
<td>-29, 0, 93, 205, 316, 482, 649</td>
</tr>
</tbody>
</table>

A These values shall be used for reference measurement (see S42.2.2).

S42.2.2 Reference Measurement—The accuracy test as specified in S42.2 shall be referred to as a “reference measurement” when performed at the conclusion of another test listed in Table S15. The reference measurement shall only be conducted at the temperatures that are specified for a reference measurement in Table S15. Performance shall conform to S39.2.2.

S42.3 Response Time—Resistance thermometers and thermocouple sensors shall be tested in accordance with the conditions of Table S16. The low or high temperature test shall be used depending upon the configuration and the type of resistance thermometer or thermocouple sensor criteria in Table S17. The time it takes the standard cylinder output to rise from an equivalent temperature from T₁ to T₂ in Table S16 shall be the standard cylinder response time. The standard cylinder response time shall be within the values listed in Table S16 for at least six consecutive trials not counting those performed in establishing the proper temperature bath conditions (temperature, orientation, stirrer speed, and so forth). The response time of the resistance thermometers and thermocouple sensors shall be the average of at least six readings taken during at least six consecutive trials where the standard cylinder was within the values specified in Table S16. The test conditions of the resistance thermometers and thermocouple sensors are also those contained in Table S17. Performance shall conform to S39.3.

S42.3.1 Standard Cylinder—A standard cylinder shall be used for this test. The information needed to construct a standard cylinder is provided on Fig. S7. Connecting wires from the standard cylinder thermocouple shall terminate at an ice bottle, ice point reference junction or a reference junction compensated electronic indicator. If an ice bottle or ice point reference junction is used, the extension wires coming from the reference junction shall be connected to an indicator such as a potentiometer or a millivolt recorder. No matter what form of indicator is used, the indicator shall have a response time not less than two times faster than the response time of the temperature rise that the standard cylinder will measure (see Table S16). Response time measurement shall be conducted using either a stop watch or any method capable of timing to 0.2 s or better.

S42.3.2 Temperature Bath—Two temperature baths are used in performing this test. The baths shall be sufficiently large or constructed in such a manner that the temperature bath fluid will not be cooled by greater than 0.5 % of the span when either the cylinder or the filled system thermometer is immersed. The “hot” bath shall contain a variable speed stirrer. Two liquid temperature bath fluids and temperatures are

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Type</th>
<th>Temperature Range, (°C)</th>
<th>Calibration Values, (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(-40 to 400)</td>
<td>(-20, 32°, 80, 180°, 280, 380°)</td>
</tr>
<tr>
<td></td>
<td>PRT</td>
<td>-40 to 538</td>
<td>-29, 0, 93, 205, 316, 427, 527</td>
</tr>
<tr>
<td></td>
<td>KTC</td>
<td>-40 to 1500</td>
<td>-20, 32°, 200°, 400, 600°, 800, 980°</td>
</tr>
<tr>
<td></td>
<td>EM</td>
<td>-40 to 181</td>
<td>-29, 0, 93, 205, 316, 482, 649</td>
</tr>
</tbody>
</table>

A These values shall be used for reference measurement (see S42.2.2).

**TABLE S15 Calibration Temperatures**

**TABLE S16 Response Time Test Conditions**

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Low Temperature Test</th>
<th>High Temperature Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum temperature °C (°F)</td>
<td>205 (400)</td>
<td>538, 816 (1000, 1500)</td>
</tr>
<tr>
<td>Bath medium</td>
<td>Water</td>
<td>Salt</td>
</tr>
<tr>
<td>Bath temperature °C (°F)</td>
<td>82 (180)</td>
<td>505 (940)</td>
</tr>
<tr>
<td>Initial temperature °C (°F)</td>
<td>10 (50)</td>
<td>238 (460)</td>
</tr>
<tr>
<td>(Start timing) temperature Ti °C (°F)</td>
<td>27 (80)</td>
<td>305 (580)</td>
</tr>
<tr>
<td>(Stop timing) temperature T2 °C (°F)</td>
<td>62 (143.2)</td>
<td>431 (808)</td>
</tr>
<tr>
<td>Standard cylinder response time (s)</td>
<td>6.0 ± 0.2</td>
<td>8.0 ± 0.2</td>
</tr>
</tbody>
</table>
permissible for use with this test and are specified in Table S16. One fluid temperature is referred to as the “cold bath temperature”, while the other is referred to as the “hot bath temperature.”

S42.3.3 Set Up—The conditions in the hot temperature bath fluid shall be set up such that the standard cylinder response time will be within the limits specified in S39.3. Hot temperature bath fluid conditions and, thus, the standard cylinder response time, will be changed by varying the stirring parameters. The standard cylinder shall be immersed in the temperature bath fluid to the bottom of the standard cylinder collar (see Fig. S7 for location). The standard cylinder shall always be immersed in the hot temperature bath fluid in the same location and in the same orientation. The immersion depth of the standard cylinder thermocouple measuring junction and the immersion depth of the embedded configuration resistance thermometer or thermocouple sensor shall be maintained at the same level.

S42.3.4 Determining Response Time—The resistance thermometer or thermocouple sensor (or standard cylinder) shall be immersed in the hot temperature bath until there is no further indication of temperature rise. The resistance thermometer or thermocouple sensor (or standard cylinder) shall then be immersed in the cold temperature bath until there is no further indication of temperature decrease. The resistance thermometer or thermocouple sensor (or standard cylinder) shall again be immersed in the hot temperature bath. Timing shall be started when the resistance thermometer or thermocouple (or standard cylinder) indicator reaches temperature $T_1$ (see Table S16) and stopped when temperature $T_2$ is reached. The time it takes the resistance thermometer or thermocouple (or standard cylinder) to indicate the difference between temperatures $T_1$ and $T_2$ shall be defined as the response time.

S42.3.5 Conducting Response Time Test—The response time test shall be conducted by taking alternate response time measurements between the standard cylinder and the thermometer. Each alternation of the standard cylinder’s then the thermometer’s response time measurements shall be defined as a trial.

S42.4 Self-heating (Resistance Thermometers)—The self-heating test shall be conducted in a water bath under the conditions specified in S42.2. A resistance thermometer shall be immersed in the water bath to at least the minimum immersion depth and allowed to stabilize at 82°C (180°F). A series of direct currents shall be passed through the resistance thermometer elements and maintained until steady state is attained such that the power impact is successively 0.5, 1.0, 3.0, and 5.0 milliwatts. A curve of the indicated temperature versus power input shall be plotted and extrapolated to zero power input. The difference between the indicated temperature at 5 milliwatts input and the extrapolated value at the indicated temperature at zero power input is the effect due to self heating. Performance shall conform to S39.4.

S42.5 Thermal Cycling—Resistance thermometers and thermocouple sensors shall be heated and cooled for 1500 cycles in accordance with Table S18. Cycle rate shall not exceed two cycles per minute. The output of the resistance thermometers and thermocouple sensors shall be monitored during thermal cycling. Connection head temperature shall not exceed the maximum connection head temperature specified in Table S7. Prior to and following the test, a reference measurement as specified in S42.2.2 shall be conducted. Performance shall conform to S39.5.

S42.6 Over-temperature (EM Configuration)—Resistance thermometers and thermocouple sensors, while at ambient temperature, shall be quickly (within 2 s) immersed for a period of 15 ± 0.5 min in a temperature bath in which the fluid is stabilized to a temperature of 274 ± 2.8°C (525 ± 5°F). The resistance thermometer or thermocouple sensor immersion depth shall be 7.62 cm (3/4 in.) if not installed in a fixture. If the resistance thermometer or thermocouple sensor is installed in a fixture, it shall be immersed to a sufficient depth to provide an accurate bath temperature measurement. The resistance thermometers or thermocouple sensors shall then be quickly immersed in another temperature bath containing the same fluid stabilized at a temperature of 288 ± 2.8°C (550 ± 5°F) to the specified depth for a period of 2 ± 0.05 min. The resistance thermometers or thermocouple sensors shall then be quickly immersed in the first temperature bath in which the fluid is stabilized at a temperature of 274 ± 2.8°C (525 ± 5°F) to the specified depth for a period of 15 ± 0.5 min. The output of the resistance thermometers or thermocouple sensors shall be monitored during this test. The resistance thermometers or thermocouple sensors shall reach the bath fluid temperature within 1 min after immersion into a temperature bath whether or not a text fixture is used. A reference measurement shall be performed at the conclusion of this test. Performance shall conform to S39.6.

S42.7 Terminal Strength (TW and EM Configurations)—With the resistance thermometers and thermocouple sensors firmly held in a holding fixture, a static tensile load of 2.27 kg (5 lb) shall be applied to each connecting wire simultaneously for 15 min for the thermowell configuration. For the embedded configuration, a static tensile load of 2.27 kg (5 lb) shall be applied to each connecting wire separately. The direction of the load shall be along the longitudinal axis of the resistance thermometers and thermocouple sensors. A reference measurement shall be performed at the conclusion of this test. The performance shall conform to S39.7.

S42.8 Connecting Wire End Closure—During this test, the resistance thermometers and thermocouple sensors of the thermowell configuration shall be removed from the connection head. No end cap shall be threaded over the connector receptacle of the resistance thermometers and thermocouple sensors of the bare bulb configuration. Connecting wire end closure shall meet the requirements specified in S39.8.

S42.8.1 Vacuum Portion—The desiccator shall be half filled with water and evacuated of dissolved air. The resistance
thermometers and thermocouple sensors shall be immersed in this desiccator. The desiccator shall then be subjected to an absolute pressure of 27.5 kPa ± 3.5 kPa (4.0 ± 0.5 lb/in.²) for 15 min. The connecting wire end closure shall be observed for evidence of air leaks.

S42.8.2 Pressure Portion—The resistance thermometers and thermocouple sensors shall be placed inside a pressure

<table>
<thead>
<tr>
<th>Temperature Range, °C (°F)</th>
<th>Cycle Temperature, °C (°F) ±10 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>-51 to 205 (-60 to 400)</td>
<td>182 (360) 205 (400)</td>
</tr>
<tr>
<td>-40 to 538 (-40 to 1000)</td>
<td>38 (100) 482 (900)</td>
</tr>
<tr>
<td>-40 to 816 (-40 to 1500)</td>
<td>93 (200) 649 (1200)</td>
</tr>
</tbody>
</table>
chamber and the pressure chamber shall be hydrostatically pressurized with water to 172.4 ± 3.5 kPa (25 ± 5 lb/in.²) for a period of no less than 15 ± 0.5 min.

S42.8.3 Post Test Measurements—At the conclusion of this test, an insulation resistance test followed by a reference measurement shall be performed. Performance shall conform to S39.8.

S42.9 Enclosures (TW and BB Configurations)—The resistance thermometers and thermocouple sensors of the thermowell configuration shall be tested with the thermowell attached to the connection head extension and a threaded plug inserted into the connection head conduit connection. The resistance thermometers and thermocouple sensors of the bare bulb configuration shall be tested with an end cap threaded over the connector receptacle. The test shall consist of a solid stream of water from a 2.54 cm (1 in.) diameter nozzle at a rate of 246 L (65 gal) per minute. The stream shall be directed on all surfaces of the equipment and its mounting surface from a maximum distance of 3.048 m (10 ft) and for a minimum of 60 min.

S42.10 Salt Spray—Resistance thermometers and thermocouple sensors shall be subjected to the salt spray test in accordance with ASTM B 117. The salt spray test shall run for a duration of 96 h. The salt solution shall be 5 ± 1% concentration (5 parts by weight of salt in 95 parts by weight of water). At the conclusion of this test, an insulation resistance test followed by a reference measurement shall be performed. Performance shall conform to S39.10.

S42.10.1 Thermowell Configuration—The resistance thermometer or thermocouple sensor shall be removed from the connection head when the test has reached the 48 h point. A plug shall be threaded into the connection head conduit connection (see Fig. S3) and a thermowell shall be threaded onto the connection head extension. The connection head (including connection head extension, plug, and thermowell) and the resistance thermometer or thermocouple sensor shall be separately subjected to the salt spray test.

S42.10.2 Bare Bulb Configuration—The resistance thermometers and thermocouple sensors shall be subjected to the salt spray test without an end cap threaded over the connector receptacle.

S42.11 Spring Loading (TW Configuration)—Resistance thermometers and thermocouple sensors shall be mounted in a jig and compressed 7.62 cm (3 in.) three successive times. The compressive force of the spring shall be measured. Performance shall conform to S39.11.

S42.12 Vibration—The vibration test shall be in accordance with MIL-S-901 grade A, class I, type C for lightweight equipment. Resistance thermometers and thermocouple sensors shall be mounted to simulate actual installation. Resistance thermometers and thermocouple sensors shall be mounted no less than 7.62 cm (3 in.) from the side and 7.62 cm (3 in.) from the rear of the platform. Output during the test shall be monitored. A reference measurement shall be performed at the conclusion of this test. Performance shall conform to S39.12.

S42.12.1 Exploratory Test:

(1) Maintain each discrete frequency from 5 to 100 Hz at 1 Hz intervals for a minimum of 15 s, or a sweep rate that shall not exceed 4 Hz per minute.

(2) Displacement or acceleration shall be as specified in Table S19.

(3) Frequencies and locations where resonance occurs during this test shall be noted.

S42.12.2 Variable Frequency Test:

(1) Discrete frequency interval of 1 Hz.

(2) Frequency range 5 to 100 Hz.

(3) Each discrete frequency shall be maintained for a minimum of 5 min.

(4) Displacements shall be as specified in Table S19.

(5) Frequencies and locations where resonance occurs during this test shall be noted.

S42.12.3 Endurance Test:

(1) The resistance thermometers and thermocouple sensors shall be subjected to a 2-h endurance run at each resonance.

(2) Displacement or acceleration shall be the variable frequency test values specified in Table S19.

(3) If no resonance is found, a 2-h performance run shall be performed at 100 Hz. A reference measurement shall be performed after the conclusion of the vibration test. Performance shall conform to S39.12.

S42.13 Shock—Shock tests shall be in accordance with MIL-S-901 grade A, class I, type C for lightweight equipment. Resistance thermometers and thermocouple sensors shall be mounted to simulate actual installation. Resistance thermometers and thermocouple sensors shall be mounted no less than 7.62 cm (3 in.) from the side and 7.62 cm (3 in.) from the rear of the platform. Output during the test shall be monitored. A reference measurement shall be performed at the conclusion of this test. Performance shall conform to S39.13.

S42.14 Pressure (EM Configuration)—The resistance thermometers and thermocouple sensors under test, which will be used only for this one test, shall be installed in a fixture made from mild steel. The critical dimensions to which the fixture shall conform are shown in Fig. S7. The entire counterbored 1.9 cm (⅝-in.) diameter surface shall be babbitted over, using babbitt that conforms to grade 2 of Specification B 23, flush with the top of the test fixture. The insulation resistance between each connecting wire and the babbitt surface shall then be measured. The babbitt surface shall then be exposed to a pressure of 12.4 MPa (1800 ± 10 lb/in.²) for 5 ± 0.25 min. After completion of this test, the insulation resistance shall be measured in the same manner as before the test. The fixture shall be unbabbitted and a reference measurement shall be performed. Performance shall conform to S39.14.

<table>
<thead>
<tr>
<th>Frequency Range, (Hz) (incl)</th>
<th>Table Displacement Peak to Peak</th>
<th>Variable Frequency Test, µin. (in.) Peak to Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 20</td>
<td>508 ± 100</td>
<td>1524 ± 300</td>
</tr>
<tr>
<td></td>
<td>(0.020 ± 0.004)</td>
<td>(0.060 ± 0.012)</td>
</tr>
<tr>
<td>21 to 50</td>
<td>254 ± 50</td>
<td>1016 ± 200</td>
</tr>
<tr>
<td></td>
<td>(0.010 ± 0.002)</td>
<td>(0.040 ± 0.008)</td>
</tr>
<tr>
<td>51 to 100</td>
<td>127 ± 25</td>
<td>508 ± 100</td>
</tr>
<tr>
<td></td>
<td>(0.005 ± 0.001)</td>
<td>(0.020 ± 0.004)</td>
</tr>
</tbody>
</table>
S42.15 Scoring—The resistance thermometers and thermocouple sensors under test, which will be used only for this one test, shall be installed in a fixture made from mild steel. The critical dimensions to which the fixture shall conform are shown in S39. The resistance thermometers and thermocouple sensors under test shall not contain a babbitt topping, and the connecting wire shall be severed. The entire 1.9 cm (¾ in.) diameter counterbored surface shall be babbitted over using babbitt that conforms to Grade 2 of Specification B 23 with 3 mm ± 254 µm (0.12 ± 0.01 in.) of the resistance thermometers and thermocouple sensors protruding above the babbitt surface. The protruding tip of the resistance thermometers and thermocouple sensors shall be brought into contact with a 5.08 cm ± 254 µm (2.00 ± 0.01 in.) diameter shaft that is rotating at 3000 ± 30 r/min. The shaft shall be made from carbon steel having a Brinell hardness between 170 and 180 and a surface finish between 15 and 25 root mean square (rms). A force of 3.63 kg ± 454 g (8 ± 1 lb.) shall be applied to the resistance thermometers and thermocouple sensors to ensure contact with the circumference of the shaft during the test. The resistance thermometers and thermocouple sensors shall be oriented so that the axis perpendicular to their sensor tip face shall intersect and be perpendicular to the longitudinal axis of the shaft. Prior to the start of the test, the shaft and the fixture shall be cleaned with a suitable solvent and wiped dry. A stylus trace of the shaft surface parallel to the axis of the shaft shall be performed at six equally spaced intervals around the circumference of the shaft. No lubrication shall be used between the resistance thermometers and thermocouple sensors and the shaft during the scoring test. The rotating shaft shall remove 2.54 mm ± 254 µm (0.10 ± 0.10 in.) of material from the protruding tip of the resistance thermometers or thermocouple sensors. Upon completion of the test, removal of any babbitt from the surface of the shaft shall be accomplished by the use of 20% sodium hydroxide solution. A stylus trace of the shaft surface parallel to the axis of the shaft shall be performed at the same six equally spaced intervals around the circumference of the shaft. Performance shall conform to S39.15.

S43. Inspection

S43.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

1. Qualification testing, and
2. Quality conformance testing.

S43.2 Qualification Testing:

S43.2.1 Sample Size—Unless otherwise specified, two resistance thermometers and thermocouple sensors of each configuration and range shall be subjected to qualification testing.

S43.2.2 General Examination and Tests—Qualification inspection shall consist of the general examination and tests specified in Table S20 in the order listed. Any deviation in the test order shall first be approved by the purchaser.

S43.2.3 Acceptance Criteria—The resistance thermometers and thermocouple sensors shall meet all the requirements of the general examination and tests listed in Table S20.

S43.3 Quality Conformance Inspection:

S43.3.1 Inspection Lot—An inspection lot shall consist of all resistance thermometers and thermocouple sensors of the same classification, produced under essentially the same conditions and offered for delivery at the same time.

S43.3.2 Group A General Examination and Test—Resistance thermometers and thermocouple sensors in each lot shall be subjected to the group A general examination and test specified in Table S20 in the order listed.

S43.3.3 Group B General Examination and Test—A sample resistance thermometer and thermocouple shall be randomly selected from each lot of 100 or more units, as appropriate, for the tests specified in Table S20. Group B tests shall be performed in the order listed on resistance thermometers and thermocouple sensors that have passed group A tests.

S43.3.4 Acceptance Criteria:

S43.3.4.1 Acceptance Criteria for Group A—The resistance thermometers and thermocouple sensors shall meet all the requirements of the group A general examination and tests in order to receive group A quality conformance inspection approval.

S43.3.4.2 Acceptance Criteria for Group B—Selected resistance thermometers and thermocouple sensors shall have passed the group A tests. If any resistance thermometer or thermocouple sensor fails in any test, no resistance thermometer or thermocouple sensor shall be accepted for quality conformance inspection until the contractor has determined the cause of the defect and has taken the necessary action to correct or eliminate the defects from resistance thermometers or thermocouple sensors on hand. The failed test and any other test required shall be repeated to demonstrate that the corrective action will enable the resistance thermometers or thermocouple sensors to conform to the requirements of this specification.

S43.4 Test Conditions—Except where the following factors are variables, the tests in this specification shall be conducted under the following conditions:

1. Calibration bath temperature shall be plus or minus 2.8°C (5°F) from the specified temperature.

<table>
<thead>
<tr>
<th>Examination and Test</th>
<th>Performance Requirement</th>
<th>Test Method</th>
<th>Applicable Configurations</th>
<th>Conformance</th>
</tr>
</thead>
<tbody>
<tr>
<td>General examination</td>
<td>S39.1</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group A</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>S39.2</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Accuracy</td>
<td>S39.3</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Response time</td>
<td>S39.4</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Self heating</td>
<td>S39.5</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Thermal cycling</td>
<td>S39.6</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Over-temperature</td>
<td>S39.7</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Terminal strength</td>
<td>S39.8</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Connecting wire end</td>
<td>S39.9</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Enclosure</td>
<td>S40.0</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Spiral loading</td>
<td>S40.1</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Vibration</td>
<td>S40.2</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Shock</td>
<td>S40.3</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Pressure</td>
<td>S40.4</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
<tr>
<td>Scoring</td>
<td>S40.5</td>
<td>TW, BB, EM</td>
<td>X</td>
<td>Group B</td>
</tr>
</tbody>
</table>
(2) Resistance thermometer element excitation current shall be 1.0 ± 0.1 mA dc.

(3) Maximum immersion into the temperature bath shall be as follows:
   (a) TW configuration—Immersion shall be to the thermowell insertion length minus 1.27 cm (0.5 in.).
   (b) BB configuration—Immersion shall be to the “E” dimension minus the thread length 2.23 cm (0.875 in.).
   (c) EM configuration—Each resistance thermometer or thermocouple sensor shall be placed in an individual stainless steel tube and packed with fine aluminum oxide powder. The stainless steel tube shall be immersed in the temperature bath fluid to a depth such that further immersion does not produce a change in the equivalent indicated temperature of more than twice the temperature bath fluid gradient.

(4) Unless otherwise specified, the test shall be performed with a sensor input current of 1 mA.

S43.5 General Examination:

S43.5.1 Visual Examination—Resistance thermometers and thermocouple sensors shall be given a thorough examination to determine that they conform to this specification and applicable drawings with respect to material, finish, workmanship, construction, assembly, dimensions, weight, marking of identification, and information plates. This examination shall be limited to those examinations that may be performed without disassembling the resistance thermometers and thermocouple sensors in such a manner that their performance, durability, or appearance will be affected.

S43.5.2 Radiographic Examination (TW and BB Configuration)—When required, the radiographic examination shall ensure that the resistance thermometer element, the thermocouple sensor’s measuring junction, and the connecting wires meet the requirements of S38.2.

S43.5.3 Sheath Straightness (TW Configuration)—A plain ring gauge having a 6.53 cm ± 2.54 µm (0.2570 ± 0.0001 in.) diameter and a length which is at least the thermowell insertion length shall be used to verify the sheath straightness. The sheath shall pass through the plain ring gauge until it hits the first spring stop.

S44. Certification

S44.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test result shall be furnished. It is recommended that all test data remain on file for three years at the manufacturer’s facility for review by purchaser upon request.

S45. Product Marking

S45.1 Product marking requirements shall be specified in the acquisition requirements.

S45.2 Identification Plate—The identification plate shall include at a minimum the following:

(1) Nomenclature,
(2) Contractor’s part number,
(3) National Stock Number (NSN),
(4) Contract number,
(5) Detailed specification number,
(6) Contractor’s name or CAGE code, and
(7) Temperature range.

S45.3 Sheath (TW and BB Configurations)—Each sheath shall be clearly and permanently marked, that is, engraved or electronically etched with the Commercial and Government Entity (CAGE) number, the classification variables as specified in B4, and a model number.

S45.4 Metallic Tag (EM Configuration)—A metallic tag shall be placed at the end of the connecting wires opposite the sheath and shall be clearly and permanently marked with the same information as required in S45.3. The following notice shall be placed on the opposite side of the tag:

NOTICE

Reattach this tag to the connecting wires after bearing installation and keep affixed to the connecting wires when the bearing is placed in service.

S45.5 Connecting Metal Link (TW Configuration)—The connecting metal links on the connection head terminal board for resistance thermometers shall be marked “R” and “W,” respectively, for the red and white insulated connecting wires. The connecting metal links on the connection head terminal board for thermocouple sensors shall be marked “Y (+)” and “R(-)” for the yellow and red insulated connecting wires.

S45.6 Connector Receptacle (BB Configuration)—The connector receptacle pins for resistance thermometers with platinum elements shall be marked “B” for the single connecting wire on one side of the resistance thermometer element and shall be marked “A” and “C” for the two connecting wires on either side of the resistance thermometer element. The connector receptacle pins for resistance thermometers with nickel elements shall be marked “A” and “B” for the two connecting wires on each side of the resistance thermometer element. The connector receptacle pins for thermocouple sensors shall be marked “(+)” and “(-)” for the positive and negative connecting wire respectively.

S45.7 Connecting Head Plate (TW Configuration)—An identification plate shall be affixed to the connecting head cap.

S46. Packaging and Package Marking

S46.1 Packaging and package marking shall be in accordance with Section 15.

S47. Quality Assurance Provisions

S47.1 Warranty—Special warranty requirements shall be specified in the acquisition requirements. Otherwise, the standard commercial warranty applies.
The following appendix to supplementary requirements established for U.S. Naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the standard (ASTM F 2362) and this supplement’s appendix, the requirements of this supplement’s appendix shall take precedence for equipment acquired by this supplement’s appendix. This document supercedes MIL-S-24795, Sensors, Temperature, Fiber Optic (Naval Shipboard Use), for new ship construction.

S48. Scope

S48.1 This supplement covers single-channel, fiber optic temperature sensors designed to meet the requirements for use onboard naval ships.

S48.2 This specification covers the requirements for single-channel, fiber optic temperature sensors for general applications. The fiber optic temperature sensor usually consists of the sensor head that is in contact with the measured media, embedded in babbitt material, or housed inside a thermowell. Using connectorized fiber optic cable, a separate optoelectronics module translates the optical input to a continuous linear proportional analog electrical signal or other output signal such as optical or digital.

S48.3 The U.S. Government preferred system of measurement is the metric SI system. However, since this item was originally designed using inch-pound units of measurement, in the event of conflict between the metric and inch-pound units, the inch-pound units shall take precedence.

S49. Referenced Documents

S49.1 Commercial Documents:

S49.1.1 ASTM Standards:

B 23 Specification for White Metal Bearing Alloys Known Commercially as “Babbitt Metal”

B 117 Test Method for Salt Spray (Fog) Testing

D 542 Test Method for Index of Refraction of Transparent Organic Plastics

D 570 Test Method for Water Absorption of Plastics

ANSI/ISA S37.1 Electrical Transducer Nomenclature and Terminology

ASME PTC 19.3:1 Thermowells (Power Test Codes, Instrumentation and Apparatus, Part 3, Temperature Measurement)

RS-422 Electrical Characteristics of Balanced Voltage Digital Interface Circuit

S49.2 Government Documents:

S49.2.1 Military Standards:

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)

MIL-STD-461 Requirements for Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

MIL-STD-2042 Fiber Optic Topology Installation Standard Methods for Naval Ships

S49.2.2 Military Specifications:

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment Systems, Requirements for

MIL-C-5015 Connector, Electrical, Circular Threaded, AN Type, General Specification for

MIL-S-19622 Stuffing Tubes, Nylon; and Packing Assemblies; General Specification for

MIL-S-19622/1 Stuffing Tubes, Straight, Nylon

MIL-S-19622/17 Stuffing Tube, Nylon, Size 2: Packing Assemblies for

MIL-E-24142 Enclosures for Electrical Fittings and Fixtures, General Specification for

MIL-E-24142/3 Enclosure for Electrical Fittings and Fixtures, Submersible, Size 6 by 9 (15 Foot)

MIL-M-24794 Material, Index Matching, Fiber Optics

MIL-F-49291 Fiber, Optical, (Metric), General Specification for

MIL-C-83522 Connectors, Fiber Optic, Single Terminus, General Specification for

MIL-C-83522/16 Connector, Fiber Optic, Single Terminus, Plug, Adapter Style, 2.5 Millimeter Bayonet Coupling, Epoxy

MIL-C-83522/17 Connector, Fiber Optic, Single Terminus, Adapter, 2.5 Millimeter Bayonet Coupling, Bulkhead Panel Mount

MIL-C-83522/18 Connector, Fiber Optic, Single Terminus, Adapter, 2.5 Millimeter Bayonet Coupling, PC Mount

MIL-C-85045 Cables, Fiber Optic, (Metric), General Specification for

MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type with

MS3456 Connector, Plug, Electrical, Rear Release, Crimp Contact, AN Type

S50. Terminology

S50.1 Terminology Defined—Terms marked with (ANSI/ISA S37.1) are taken directly from ANSI/ISA S37.1 (R-1982) and are included for the convenience of the reader.

S50.2 Definitions—Terminology consistent with ANSI/ISA S37.1 shall apply, except as modified by the definitions listed as follows:

S50.2.1 ambient conditions—conditions such as pressure and temperature of the medium surrounding the case of a sensor (ANSI/ISA S37.1).

S50.2.2 babbitt—metal material commonly used in bearing and temperature sensor installations which wears in with equipment operation providing a wear surface and heat transfer
medium. Babbit is softer than the base or substrate material and softer than mating component materials, where applicable.

S50.2.3 bare-bulb type sensor head—sensor head design where the sensing element is exposed directly to the process fluid being measured.

S50.2.4 calibration—test during which known values of measurands are applied to the sensor and corresponding output readings are recorded under specific conditions (ANSI/ISA S37.1).

S50.2.5 embedded type sensor head—sensor head design which is embedded in babbitt material which isolates the sensor element from the process fluid and, in some instances, moving or rotating components, but still allows the temperature to be monitored.

S50.2.6 environmental conditions—specified external conditions such as shock, vibration and temperature to which a sensor may be exposed during shipping, handling, and operation (ANSI/ISA S37.1).

S50.2.7 error—algebraic difference between the indicated value and the true value of the measurand (ANSI/ISA S37.1).

S50.2.8 fiber optic temperature sensor—a device that converts sensed temperature to a proportional output signal via changes in fiber optic properties. The fiber optic temperature sensor normally consists of a sensor head, opto-electronics module, and connectorized fiber optic cable.

S50.2.9 hysteresis—the difference in sensor output when compared at the same temperature under the same environmental conditions with one data point taken with ascending temperature and another with descending temperature.

S50.2.10 operating environmental conditions—environmental conditions during exposure to which a sensor must perform in some specified manner (ANSI/ISA S37.1).

S50.2.11 optical—involving the use of light sensitive devices to acquire information.

S50.2.12 optical fiber—a very thin filament or fiber, made of dielectric materials, that is enclosed by material of lower index of refraction and transmits light throughout its length by internal reflections.

S50.2.13 opto-electronics module—a component of the fiber optic temperature sensor that contains the optical source and detector, and signal conditioner devices necessary to convert the sensed temperature to a specified output signal.

S50.2.14 output—electrical or numerical quantity, produced by a sensor or measurement system, that is a function of the applied measurand.

S50.2.15 range—measurand values over which a sensor is intended to measure, specified by their upper and lower limits (ANSI/ISA S37.1).

S50.2.16 repeatability—ability of a sensor to reproduce output readings when the same measurand value is applied to it consecutively, under the same conditions, and in the same direction (ANSI/ISA S37.1).

S50.2.17 response time—the time required for a sensor to indicate a step change in temperature or the time difference between an actual step change in temperature applied and the corresponding change in sensor output.

S50.2.18 sensitivity factor—the ratio of fiber optic temperature sensor output signal percentage change of span to applied bath temperature percentage change of span.

S50.2.19 sensor element—that part of the sensor that responds directly to the measurand (ANSI/ISA S37.1).

S50.2.20 sensor head—the transduction element of a fiber optic temperature sensor that detects temperature via changes in optical properties.

S50.2.21 sheath—the protective covering of a sensor element.

S50.2.22 SI (Le Systeme International d’Unites) units—units of measurement recognized by the CIPM (Comite’ International des Poids et Mesures).

S50.2.23 signal conditioner—an electronic device that makes the output signal from a transduction element compatible with a readout system.

S50.2.24 span—the algebraic difference between the limits of the measurement range.

S50.2.25 static error band—the maximum deviation from a straight line drawn through the coordinates of the lower range limit at specified sensor output and the upper range limit at specified output expressed in percentage of sensor span.

S50.2.26 thermowell—a pressure tight receptacle adapted to receive a temperature sensing element and provided with the external threads or other means for pressure tight attachment to the vessel.

S50.2.27 thermowell type sensor head—sensor head design which is intended to be used with a thermowell which isolates the sensor element from the process fluid being measured while maintaining the pressure boundary.

S50.2.28 warm-up time—the time required for a sensor to operate within specified requirements after being re-energized from a cold (ambient) state.

S51. Classification

S51.1 Design Type—The fiber optic temperature sensor shall consist of a series of designations which shall be assigned and listed in the format below.

Example: ASTM F2362S48-T4-DC-A-VC-2

<table>
<thead>
<tr>
<th>Specification</th>
<th>Type</th>
<th>Input Power</th>
<th>Opto-Electronics Module</th>
<th>Signal Output</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2362S48</td>
<td>T4</td>
<td>DC</td>
<td>A</td>
<td>VC</td>
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<td></td>
<td></td>
<td>S51.2</td>
<td>S51.3</td>
<td>S51.4</td>
<td>S51.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S51.6</td>
</tr>
</tbody>
</table>

S51.2 Type—The sensor head type shall be designated as follows:

T1—Thermowell (see Fig. S8 and Fig. S9)
T2—Thermowell (see Fig. S8 and Fig. S9)
T3—Thermowell (see Fig. S8 and Fig. S9)
T4—Thermowell (see Fig. S8 and Fig. S9)
EM—Embedded (Bearing Applications, see Fig. S8 and Fig. S10)
B1—Bare-bulb (see Fig. S11)
B2—Bare-bulb (see Fig. S11)

S51.3 Input Power—The input power required to operate the opto-electronics module shall be designated as follows:

DC—28 V direct current (Vdc)
AC—115 V alternating current (Vac)

S51.4 Opto-electronics Module—The opto-electronics module type shall be designated as follows:
A—Junction box enclosure
B—Control console module
C—Monitoring and alarm panel module

S51.5 Signal Output—The signal output shall be designated as follows:

<table>
<thead>
<tr>
<th>Signal Designation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4 to 20 mA dc</td>
</tr>
<tr>
<td>VA</td>
<td>0 to 5 Vdc</td>
</tr>
<tr>
<td>VB</td>
<td>0 to 10 Vdc</td>
</tr>
<tr>
<td>VC</td>
<td>0 to 12 Vdc</td>
</tr>
<tr>
<td>VS</td>
<td>Specified</td>
</tr>
</tbody>
</table>

FIG. S8 Thermowell Type Sensor Head Assembly
O—Digital optical output
E—Digital electrical output
S51.6 Range—The sensor measurement range shall be designated as follows:
1: -40 to 150°C (-40 to 302°F)
2: 0 to 300°C (32 to 572°F)
3: -40 to 300°C (-40 to 572°F)

S52. Ordering Information
S52.1 The purchaser shall provide the manufacturer with all of the pertinent application data shown in accordance with S52.2. If special application operating conditions exist that are not shown in the acquisition requirements, they shall also be described.

S52.1 Acquisition Requirements—Acquisition documents should specify the following:
1. Title, number, and date of this specification,
2. Quantity of fiber optic temperature sensors required,
3. Fiber optic temperature sensor classification required:
   (a) Sensor type,
   (b) Input power,
   (c) Opto-electronics module,
   (d) Signal output, and
   (e) Range.
4. When qualification inspection is required,
5. Final disposition of qualification test samples,
6. National Stock Number (NSN) if available,
(7) Unique product marking requirements, and
(8) Unique preservation, packaging and marking require-ments.

S53. Materials and Manufacture

S53.1 Sensing Elements—The materials for all wetted parts shall be selected for long term compatibility with the process medium. For example, corrosion resistant steel or monel are compatible with long term exposure to seawater.

S53.2 Metals—Unless otherwise specified herein, all metals in the construction of the sensor shall be corrosion resistant. Dissimilar metals shall not be used in close physical contact with each other unless suitably finished to prevent electrolytic corrosion. Materials used to fabricate the sensor head for the embedded configuration shall have a Brinell hardness less than 170 to ensure that shaft scoring does not occur.

S53.3 Flammable Materials—Materials used in the construction of the sensor shall, in the end configuration, be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure and temperature to be expected in the application. Fire retardant additives may be used provided they do not adversely affect the specified performance requirements of the basic materials. Fire retardance shall not be achieved by use of nonpermanent additives to the basic material.

S53.4 Fungus Resistant Materials—Materials used in the construction of the sensor shall be fungus inert materials.

S53.5 Solvents, Adhesives, and Cleaning Agents—If any chemicals or cements are used in bonding of internal components, no degradation shall result during in-service use.

S53.6 Refractive Index Matching Gels, Fluids, or Compounds—Refractive index matching gels, fluids, or compounds shall be in accordance with MIL-M-24794 and shall not produce toxic, corrosive, or explosive byproducts. The material is subject to a toxicological data and formulations review and inspection, for safety of material, by the purchaser. The index matching material shall be either silicone or aliphatic hydrocarbon material and shall be clear and transparent. The index matching material shall have an index of refraction of 1.46 ± 0.01 as tested in accordance with Test Method D 542 when exposed to operating temperature extremes between -28°C and +85°C (-18.4 and 185°F). The index matching material shall not flow at elevated temperatures. The index matching material shall remain clear and transparent when tested for water absorption in accordance with Test Method D 570. The index matching material shall have a shelf life not less than 36 months at 25 ± 5°C (77 ± 9°F). The 36 month period commences on the date of adhesive manufacture.

S54. Physical Properties

Fiber optic temperature sensors convert the thermal energy surrounding the sensor head to a continuous linear analog dc signal or specified digital output throughout a specified measurement range. The fiber optic temperature sensor shall consist of a sensor head, opto-electronics module, and fiber optic cable interconnect. All parts of the fiber optic temperature sensor shall be interchangeable with the appropriate replace-ment parts with respect to form, fit, and function, and maintain the specified accuracy requirements.

S54.1 Sensor Head—The sensor head shall detect the surrounding temperature. The sensor head shall be passive in nature by detection of temperature through a change in optical properties. Neither electrical nor electronic components shall be used in the construction of the sensor head.

S54.1.1 Thermowell Type—The sensor head shall be constructed in accordance with Fig. S8 and Fig. S9. The sensor head dimensions shall be in accordance with Fig. S8 and Fig. S9. The sensor head shall have a weight not greater than 1 kg.

S54.1.2 Embedded Type—The sensor head shall be constructed in accordance with the dimensions shown in Fig. S10. The babbitt topping material shall be in accordance with Specification B 23 (grade 2).

S54.1.3 Bare-bulb Type—The bare-bulb type sensor head dimensions shall be in accordance with Fig. S11. The sensor head shall have a weight not greater than 1 kg (2.2 lb). The sensor sheath shall be designed to withstand application conditions of 37.66 Mpa (5500 pounds per square inch), 210°C (410°F), and an open air flow velocity of 12.2 m (40 ft) per second. Conformance shall be proven by using a mathematical model approved by the Power Test Code Thermometer Wells, ASME PTC 19.3:1.

S54.2 Opto-electronics Module:

S54.2.1 Junction Box Enclosure (Type A)—The opto-electronics shall be housed in a junction box. MIL-E-24142 and MIL-E-24142/3 may be used as guidance for the junction box. At a minimum, the dimensions, mounting requirements, and cable entrance shall be in accordance with MIL-E-24142 and MIL-E-24142/3. The opto-electronics module shall have a weight no greater than 4.5 kg (9.92 lb).

S54.2.2 Control Console Module (Type B)—The opto-electronics shall be packaged in a circuit card which is a modular subassembly of a control console. Design and test requirements for the opto-electronics module shall be as specified in the acquisition requirements.

S54.2.3 Monitoring and Alarm Panel Module (Type C)—The opto-electronics shall be packaged in a module which is a subassembly of a bulkhead mounted temperature monitoring and alarm panel. Design and test requirements for the opto-electronics module shall be as specified in the acquisition requirements.

S54.3 Fiber Optic Cable:

S54.3.1 Thermowell and Bare-bulb Sensor Types—The cable used to interface the sensor head and the opto-electronics module shall have an outer diameter of a four fiber cable in accordance with MIL-C 85045. In the cable, there shall be no less than two times the number of fibers required for operation of the sensor. The cable shall be supplied with a stuffing tube (size 2, military part number M19622/1-002 in accordance with MIL-S-19662/1), and packing assembly (military part number M19622-17-0001 in accordance with MIL-S-19662/17) in accordance with MIL-S-19622, and an o-ring installed on each end of the cable to accomplish watertight penetration into the sensor head and opto-electronic module. The o-rings used shall be petroleum hydraulic fluid resistant and shall be rated to perform in high temperature applications 135°C
Embedded Sensor Type—The cable used to interface the sensor head and a local interconnection box shall be in accordance with MIL-C-85045. The cable length shall be as specified in the acquisition requirements.

Optical Fiber—Optical fiber used to transmit light between the opto-electronics module and the sensor head shall be in accordance with MIL-F-49291.

Fiber Optic Connectors, Receptacles, and Bulkhead Adapters—All fiber optic connectors, receptacles, and bulkhead adapters shall be in accordance with MIL-C-83522 and MIL-C-83522/16,17, and 18, respectively. The fiber optic cable for the thermowell sensor type shall be terminated at both ends with connectors. The fiber optic cable for the embedded and bare-bulb sensor configurations shall be terminated with a connector at the end which interfaces with the opto-electronic module. MIL-STD-2042 method 5B1 may be used as guidance. The connectors and receptacles shall be mounted inside the sensor head (thermowell sensor type only) and the opto-electronic module.

Electrical Input Power—Nominal steady-state power supply requirements for ac shall be 115 ± 8 Vac, 60 Hertz, single phase. Nominal steady-state power supply requirements for dc shall be 28 ± 4.5 Vdc. The sensor shall operate with power supply variations as specified (see S58.8.1 through S58.8.6).

Output Signal:

Current Output—When a current output is required, the output signal shall be directly proportional to the temperature being measured. The 4 mA output shall correspond to the lower temperature range value and the 20 mA output shall correspond to the upper temperature range value. The current output shall remain accurate regardless of external load resistance variations over a range of 0 to 250 Ω.

Voltage Output—When a voltage output is required, the output signal shall be directly proportional to the temperature being measured. The lower dc voltage output shall correspond to the lower temperature range value and the higher dc voltage output shall correspond to the upper temperature range value. The voltage output shall remain accurate regardless of external load resistance greater than 1000 Ω. Typical voltage outputs include 0-5 Vdc, 0-10 Vdc and 0-12 Vdc.

Digital Optical Output—When a digital optical output is required, the output signal specifications shall be specified in the acquisition requirements.

Digital Electrical Output—When a digital electrical output is required, the electrical characteristics shall be those specified in EIA standards RS-422 for balanced voltage digital interface circuitry or as specified in the acquisition requirements. The data format shall also be specified in the acquisition requirements.

Electrical Connectors—A single electrical receptacle in accordance with MIL-C-5015 shall be used to interface with the input power and linear output signal to the opto-electronics module. When a digital optical or digital electrical output signal is specified, connectors shall be as specified in the acquisition requirements. The appropriate connector assembly and pin designations for each of the possible fiber optic temperature configurations shall be as specified as follows:

DC Input Power—The receptacle mounted to the opto-electronics module shall be classification MS3452W14S-5PX in accordance with MS3452. Receptacle pin “A” shall be positive 28 Vdc input power, pin “B” shall be negative 28 Vdc input power, pin “C” shall be the case ground, pin “D” shall be positive mA or high Vdc output signal, and pin “E” shall be the negative mA or low Vdc output signal. The mating plug supplied with the fiber optic temperature sensor shall be classification MS3456W14S-5SX in accordance with MS3456.

AC Input Power—The receptacle mounted to the opto-electronics module shall be classification MS3452W14S-5PX in accordance with MS3452. Receptacle pin “A” shall be positive 115 Vac input power, pin “B” shall be input power return, pin “C” shall be the case ground, pin “D” shall be positive mA or high Vdc output signal, and pin “E” shall be the negative mA or low Vdc output signal. The mating plug supplied with the fiber optic temperature sensor shall be classification MS3456W14S-5SX in accordance with MS3456.

Adjustments—A means may be provided for adjusting the output signal of the opto-electronics module for calibration purposes. If provided, the adjustments shall be situated in the opto-electronics module so that calibrations can be performed with the fiber optic temperature sensor energized.

Fuses—The opto-electronics module shall not be fused.

Performance Requirements

Accuracy—The fiber optic temperature sensor output signal accuracy shall be within ± 1 % of span (see S58.1).

Repeatability—The fiber optic temperature sensor output signal repeatability at each temperature point shall not change in value more than 0.5 % of span (see S58.2).

Reference Measurement—The fiber optic temperature sensor output signal accuracy shall be within ± 1 % of span (see S58.3).

Sensitivity Factor—The ratio of the fiber optic temperature sensor output signal percentage change of span to applied bath temperature percentage change of span shall not be less than 0.75 nor greater than 1.25 (see S58.4).

Response Time—Response time of the fiber optic temperature sensor output signal accuracy shall not be greater than 8 s for the thermowell sensor type, not greater than 5 s for the embedded sensor type, and not greater than 15 s for the bare-bulb sensor type (see S58.5).

Warm-up Time—The fiber optic temperature sensor output signal accuracy at the bath temperature shall be within ± 1 % of span within 1 min after the sensor is energized (see S58.6).

Steady-state Supply Voltage and Frequency (AC) or Supply Voltage (DC)—The fiber optic temperature sensor output signal shall be within ± 1 % of span throughout the limits of supply voltage and frequency (see S58.7).
S55.8 Transient Voltage and Frequency (AC) or Voltage (DC)—The fiber optic temperature sensor output signal accuracy shall be within ±1 % of span when subjected to transient voltage and frequency (see S58.8).

S55.9 Insulation Resistance—The insulation resistance of the fiber optic temperature sensor between circuits and between circuits and ground shall not be less than 10 megohms (see S58.9).

S55.10 Power Interruption—The fiber optic temperature sensor output signal accuracy shall be within ±1 % of span during short duration power interruptions (see S58.10).

S55.11 Short Circuit—The fiber optic temperature sensor output signal accuracy shall be within ±1 % of span after short circuit of the output signal lines (see S58.11).

S55.12 Line Voltage Reversal (DC)—The fiber optic temperature sensor output signal accuracy shall be within ±1 % of span after reversal of the input dc power lines (see S58.12).

S55.13 Temperature—The fiber optic temperature sensor output signal accuracy shall be within ±1 % of span over the ambient temperature range of 0 to 65°C (32 to 149°F) (see S58.13).

S55.14 Enclosure—The fiber optic temperature sensor output signal accuracy shall be within ±1 % of span after exposure to a coarse stream of water (see S58.14).

S55.15 Salt Spray—No corrosion or other damage shall be evident when exposed to salt spray and the fiber optic temperature sensor output signal accuracy shall be within ±1 % of span (see S58.15).

S55.16 Over-temperature—The sensor head shall show no evidence of physical damage when exposed to the limits of over-temperature and the reference measurement results shall conform to S55.3 (see S58.16).

S55.17 Accelerated Life—The sensor head shall show no evidence of physical damage when exposed to operating conditions which simulate accelerated life and the reference measurement results shall conform to S55.3 (see S58.17).

S55.18 Vibration—The fiber optic temperature sensor shall operate without interruption and show no evidence of physical damage when exposed to vibration in accordance with MIL-STD-167-1. The reference measurement results shall conform to S55.3 (see S58.18).

S55.19 Shock—The fiber optic temperature sensor shall operate without interruption and show no evidence of physical damage when exposed to shock in accordance with MIL-S-901. The reference measurement results shall conform to S55.3 (see S58.19).

S55.20 Electromagnetic Interference (EMI) Emission and Susceptibility—The fiber optic temperature sensor shall be in accordance with the requirements of MIL-STD-461 revision E, or later: CE101 (Submarine application only), CE102, CS101, CS114, CS116, RE101, RE102, RS101, and RS103 (see S58.20).

S55.21 Pressure—The fiber optic temperature sensor shall operate without interruption when exposed to a babbitt surface pressure of 12.4 MPa (1800 psi). The reference measurement shall conform to S55.3 (see S58.21).

S56. Workmanship, Finish, and Appearance

S56.1 Cleaning and Surface Finishes—Surfaces of castings, forgings, molded parts, stampings, machined and welded parts shall be free of defects such as cracks, porosity, undercuts, voids and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn-through. There shall be no warpage or dimensional change due to heat from welding operation. There shall be no damage to adjacent parts resulting from welding.

S57. Number of Tests and Retests

S57.1 The number of tests and retests, if any, shall be specified in the acquisition requirements.

S58. Test Methods

S58.1 Accuracy—The sensitive portion of the sensor head shall be immersed in a temperature bath and the fiber optic temperature sensor output signal shall be measured at 5, 25, 50, 75 and 95 % of the fiber optic temperature sensor span. Accuracy shall conform to S55.1. The fiber optic temperature sensor output signal shall conform to S55.2.

S58.2 Repeatability—The procedure specified in S58.1 shall be repeated three successive times while maintaining temperature bath conditions. The fiber optic temperature sensor head shall be removed from the bath for not less than 2 min and re-immersed at a repeatable depth for consecutive measurements at each of the five temperature points. The fiber optic temperature sensor output signal shall conform to S55.2.

S58.3 Reference Measurement—The sensitive portion of the sensor head shall be immersed in a temperature bath and the fiber optic temperature sensor output signal shall be measured at 5, 50, and 95 % of the fiber optic temperature sensor span. System accuracy shall conform to S55.1.

S58.4 Sensitivity Factor—The sensitivity factor shall be determined using the following procedure. Immerse the sensitive portion of the sensor head in a temperature bath and allow ample time to stabilize at a temperature of 80 ± 5 °C of span. Measure both the bath temperature and the fiber optic temperature sensor output signal. Increase the bath temperature by an amount not greater than 1 % of the fiber optic temperature sensor span. Measure both the new bath temperature and the fiber optic temperature sensor output signal. Calculate the change in both bath temperature and fiber optic temperature sensor output signal as a percentage of the fiber optic temperature sensor span. Determine the ratio of the output signal percentage change to applied bath temperature percentage change in terms of fiber optic temperature sensor span. Repeat this procedure for a bath temperature decrease not greater than 1 % of span. Performance shall conform to S55.4.

S58.5 Response Time—The response of the fiber optic temperature sensor shall be determined using the following procedure:

1. Bath medium: water
2. Origin bath temperature: 10°C (50°F)
3. Destination bath temperature: 82°C (180°F)
4. Initial temperature (T1): 26°C (79°F)
5. Final temperature (T2): 62°C (144°F)
The response time shall be determined as the time required for the fiber optic temperature sensor output signal to track from T1 to T2 after the sensor head in transferred from the origin bath to the destination bath. The response time of the fiber optic temperature sensor shall be the average of not less than six readings taken during not less than six consecutive trials. Performance shall conform to S55.5.

S58.6 Warm-up Time—Warm-up time shall be determined using the following procedure. Allow the sensitive portion of the sensor head to stabilize at a bath temperature of 80 ± 5 % of the fiber optic temperature sensor span. De-energize the fiber optic temperature sensor for no less than 2 h. Energize the fiber optic temperature sensor and monitor the output signal as necessary to ensure conformance to S55.6.

S58.7 Steady-state Supply Voltage and Frequency (AC) or Supply Voltage (DC)—The fiber optic temperature sensor output signal shall be monitored for no less than 15 min at normal, maximum, and minimum steady-state voltage and frequency conditions as specified in S58.8. The fiber optic temperature sensor shall be subjected to each of the applicable power supply conditions for no less than 1 h at ambient temperatures of 0, 25, and 65°C (32, 77, and 149°F). The fiber optic temperature sensor signal output shall be measured after not less than 1 h at each test condition. This test may be performed in conjunction with the temperature test (see S58.13). Performance shall conform to S55.7.

S58.8 Transient Supply Voltage and Frequency (AC) or Supply Voltage (DC)—The fiber optic temperature sensor output signal shall be monitored at ambient temperature during each test procedure defined below. Performance shall conform to S55.8.

S58.8.1 Transient Voltage Upper Limit (AC)—With the fiber optic temperature sensor operating at a voltage of 123 Vac, the voltage shall be increased to 138 Vac, and then decreased back to the steady-state voltage of 123 Vac in a 2 s period.

S58.8.2 Transient Voltage Lower Limit (AC)—With the fiber optic temperature sensor operating at a voltage of 107 Vac, the voltage shall be decreased to 92 Vac, and then increased back to the steady-state voltage of 107 Vac in a 2 s period.

S58.8.3 Transient Frequency Upper Limit (AC)—With the fiber optic temperature sensor operating at a frequency of 62 Hz, the frequency shall be increased to 63.5 Hz, and then decreased back to the steady-state frequency of 62 Hz in a 2 s period.

S58.8.4 Transient frequency lower limit (AC)—With the fiber optic temperature sensor operating at a frequency of 58 Hz, the frequency shall be decreased to 56.5 Hz, and then increased back to the steady-state frequency of 58 Hz in a 2 s period.

S58.8.5 Transient Voltage Upper Limit (DC)—With the fiber optic temperature sensor operating at a voltage of 32.5 Vdc, the voltage shall be increased to 34.5 Vdc, and then decreased back to the steady-state voltage of 32.5 Vdc in a 2 s period.

S58.8.6 Transient Voltage Lower Limit (DC)—With the fiber optic temperature sensor operating at a voltage of 23.5 Vdc, the voltage shall be decreased to 21.5 Vdc, and then increased back to the steady-state voltage of 23.5 Vdc in a 2 s period.

S58.9 Insulation Resistance—The insulation resistance of the opto-electronics module circuits shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and the ground. The insulation resistance measurement shall be made immediately after a 2 min period of uninterrupted test voltage application. If the indication of insulation resistance meets the specified limit (see S55.9) and is steady or increasing, the test may be terminated before the end of the 2 min period. Performance shall conform to S55.9.

S58.10 Power Interruption—The fiber optic temperature sensor shall be energized and the output signal monitored at ambient temperature throughout the test. The external power supply shall be suddenly interrupted, and after an interval not less than 4 s, the power supply shall be reapplied to the fiber optic temperature sensor. Performance shall conform to S55.10.

S58.11 Short Circuit—The fiber optic temperature sensor shall be de-energized and the positive and negative electrical output terminals of opto-electronics module shall be connected directly together, with no load resistance. The fiber optic temperature sensor shall be energized for 5 min, then deenergized and the short circuit removed. The fiber optic temperature sensor shall be energized and the output signal measured at ambient temperature. Performance shall conform to S55.11.

S58.12 Line Voltage Reversal (DC)—The positive 28 Vdc power input shall be applied to connector pin “B” and the reference shall be applied to connector pin “A.” The power supply shall be energized for a period of no less than 10 min. The fiber optic temperature sensor output signal shall be measured at ambient temperature. The fiber optic temperature sensor shall be de-energized and the power supply connections shall be reversed to normal polarity. The fiber optic temperature sensor shall then be energized for no less than 5 min before the output signal is measured at ambient temperature. Performance shall conform to S55.12.

S58.13 Temperature—The fiber optic temperature sensor shall be positioned in an environmental chamber in an energized state, and shall be subjected to the following conditions consecutively:

1. Hold temperature at 0 ± 2°C (32 ± 3.6°F) for 24 h.
2. Increase temperature in steps of 10°C (18°F) at 30 min per step until 65 ± 2°C (149 ± 3.6°F) is achieved.
3. Hold temperature at 65 ± 2°C (149 ± 3.6°F) for 24 h, and
4. Reduce temperature in steps of 10°C (18°F) at 30 min per step until 25 ± 2°C (77 ± 3.6°F) is achieved.

Measure the fiber optic temperature sensor output signal at one point during the last hour of operation at each temperature.
plateau, that is 0, 25, and 65°C (32, 77, and 149°F). Performance shall conform to S55.13.

S58.14 Enclosure—The fiber optic temperature sensor head and no less than a two meter section of the attached cable interconnect shall be mounted to a surface which extends no less than 1 m (3.28 ft) beyond the sensor head on all sides so that splashing shall be produced by directing the water stream on that surface. The fiber optic temperature sensor shall be de-energized throughout the test. The water stream shall be a coarse spray with a flow rate of no less than 57 L (15 gal) per minute. The nozzle to the enclosure under test shall be approximately 2 m (6.56 ft). The distance from the nozzle to the enclosure under test shall be no less than 57 L (15 gal) per second and a head pressure of no less than 3 m (9.84 ft). A head pressure of 3 m (9.84 ft) is defined as sufficient water pressure so that if directed straight up, the stream of water shall rise to a height of no less than 3 m (9.84 ft). The distance from the nozzle to the enclosure under test shall be approximately 2 m (6.56 ft). The time of the test shall be no less than 5 min with approximately equal portions of time for spray on each surface, including joints of the enclosure and at the surface at which the enclosed equipment is mounted. The fiber optic temperature sensor components shall be examined at the immediate conclusion of the test for moisture penetration. The fiber optic temperature sensor shall be energized and the output signal monitored at ambient temperature at the conclusion the test. Performance shall conform to S55.14.

S58.15 Salt Spray (Fog)—The fiber optic temperature sensor head and no less than a 1 m (3.28 ft) section of the attached cable interconnect shall be subjected to salt spray in accordance with Test Method B 117. This test is not applicable to the embedded sensor configuration since it will be secured in a bearing. The fiber optic temperature sensor shall be de-energized throughout the test. Duration of the test shall be no less than 5 min with approximately equal portions of time for spray on each surface, including joints of the enclosure and at the surface at which the enclosed equipment is mounted. The fiber optic temperature sensor components shall be examined at the immediate conclusion of the test for corrosion and moisture penetration. The fiber optic temperature sensor shall be energized and the output signal monitored at ambient temperature at the conclusion of the test. Performance shall conform to S55.15.

S58.16 Over-temperature—The sensitive portion of the fiber optic temperature sensor head shall be rapidly transferred from ambient conditions to a temperature bath stabilized at 125% of the fiber optic temperature sensor full scale temperature. The sensor head shall remain immersed in the bath for 15 min and then returned to ambient conditions. A reference measurement (see S55.3) shall be performed at the conclusion of the over-temperature test. Performance shall conform to S55.16.

S58.17 Accelerated Life—The sensitive portion of the sensor head shall be thermally cycled between the following temperatures for 1500 cycles at a rate not greater than 2 cycles per minute:

<table>
<thead>
<tr>
<th>Sensor Range</th>
<th>Temperature Cycling Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40 to 150°C (-40 to 302°F)</td>
<td>Ambient to -30 ± 2°C (-22 ± 3.6°F)</td>
</tr>
<tr>
<td>0 to 300°C (32 to 572°F)</td>
<td>Ambient to 285 ± 2°C (545 ± 3.6°F)</td>
</tr>
</tbody>
</table>

The fiber optic temperature sensor output signal shall be monitored during thermal cycling and observed for operation without interruption. A reference measurement (see S55.3) shall be performed at the conclusion of the thermal cycling test. Performance shall conform to S55.17.

S58.18 Vibration—The fiber optic temperature sensor shall be tested in accordance with MIL-STD-167-1, type 1. Test fixtures shall be designed to simulate the shipboard installation of the sensor type. The fiber optic temperature sensor output signal shall be monitored throughout the test and visually examined for operation without interruption, especially at resonant frequencies. The fiber optic temperature sensor shall be visually examined for physical damage during and at the conclusion of the test. A reference measurement in accordance with S55.3 shall be performed at the conclusion of the test. Performance shall conform to S55.18.

S58.19 Shock—The fiber optic temperature sensor shall be fully assembled, energized, and tested in accordance with grade A, class 1, type A of MIL-S-901. Test fixtures shall be designed to simulate the shipboard installation of the sensor type. The fiber optic temperature sensor shall be visually examined for physical damage after each hammer blow and at the conclusion of the test. A reference measurement in accordance with S55.3 shall be performed at the conclusion of the test. Performance shall conform to S55.19.

S58.20 EMI Emission and Susceptibility—EMI tests shall be in accordance with the test methods specified in MIL-STD-461 revision E, or later. Performance shall conform to S55.20.

S58.21 Pressure—A reference measurement (see S55.3) shall be performed prior to the test to ensure the sensor head is not defective. The sensor head under test shall be installed in a fixture made from mild steel. The critical dimensions to which the fixture shall conform are shown on Fig. S12. The 19.05 mm (0.75 in.) diameter counterbore shall contain Specification...
B 23 (grade 2) babbitt flush with the test fixture surface. The babbitt surface shall then be exposed to a gauge pressure of 12.411 ± 0.07 MPa (1800 ± 10 pounds per square inch) for not less than 5 min. The fiber optic temperature sensor output signal shall be monitored during the test and examined for operation without interruption. The babbitt shall be removed from the 19.05 mm (0.75 in.) counterbore and a reference measurement (see S55.3) shall be performed. Performance shall conform to S55.21.

S59. Inspection

S59.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

(a) Qualification testing, and
(b) Quality conformance testing.

S59.2 Qualification Testing—Qualification testing shall be performed prior to production. Qualification testing shall be performed on samples which have been produced with equipment and procedures normally used in production. Qualification testing shall consist of the examinations and tests in the order specified in Table S21. Failure of any sensor to meet the requirements of this specification shall be cause for rejection.

S59.2.1 Sample Size—Two fiber optic temperature sensors of each lot shall be subjected to the qualification inspection. An inspection lot shall consist of all sensors of the same classification (see C4), produced under essentially the same conditions, in the same facility from the same materials and offered for delivery at the same time. One sample shall be subjected to the tests of Group I. The two samples shall be supplied with the length of cable required for the intended application, but shall not be less than 30.5 m (100 ft). The Group II test requires an additional embedded sensor due to the destructive nature of the test and shall only be accomplished for acquisitions for embedded designs.

S59.3 Quality Conformance Testing—Each sensor in each lot offered for delivery shall be subjected to the inspection listed in Table S22 and shall be conducted in the order listed.

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<thead>
<tr>
<th>Examination and Tests</th>
<th>Requirement</th>
<th>Procedure</th>
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</thead>
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<td>Group I: One sample required</td>
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<tr>
<td>General examination</td>
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<td>Steady-state voltage and frequency</td>
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<td>Transient voltage and frequency</td>
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<td>Vibration</td>
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<td>Shock</td>
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</table>

S60. Certification

S60.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test result shall be furnished. It is recommended that all test data remain on file for three years at the manufacturer’s facility for review by purchaser upon request.

S61. Product Marking

S61.1 Opto-electronics Module—Each opto-electronics module shall be permanently and legibly marked in accordance with the acquisition requirements. The following minimum information shall be provided:

(1) Nomenclature,
(2) Design classification,
(3) National Stock Number (NSN) if available,
(4) Manufacturer’s name and model number,
(5) Temperature range,
(6) Contract number, and
(7) A unique serial number from the manufacturer.
S61.2 Sensor Head—Each sensor head shall be permanently
and legibly marked in accordance with the acquisition require-
ments. The following minimum information shall be provided:
(1) Nomenclature,
(2) Design classification,
(3) National Stock Number (NSN) if available,
(4) Manufacturer’s name and model number, and
(5) A unique serial number from the manufacturer.
S61.2.1 Embedded Sensor Head—In addition to the above,
the embedded sensor type shall use a removable metal tag
which attaches to the cable interface for identification marking.
The following notice shall be marked on the opposite side of
the tag:

NOTICE
Reattach this tag to the cable interface after bearing
insulation and keep affixed after the bearing is placed
in service.

S61.3 Warning Labels—A visible label shall be affixed to
the outside of the opto-electronics module cover and shall
contain the following:

WARNING
UNTERMINATED OPTICAL CONNECTORS MAY
EMIT LASER RADIATION. DO NOT VIEW BEAM
WITH OPTICAL INSTRUMENTS AND AVOID
DIRECT EXPOSURE TO BEAM.

A visible label shall be affixed to the sensor head and the
inside of the opto-electronics module and shall contain the
following:

WARNING
INVISIBLE LASER RADIATION. AVOID EXPOSURE
TO THE BEAM.
The labels shall be yellow lettering on a black background.

S62. Packaging and Package Marking
S62.1 Fiber optic temperature sensors shall be individually
packaged and marked in accordance with Section 15.

S63.1 Warranty—Special warranty requirements shall be
specified in the acquisition requirements. Otherwise, the stan-
dard commercial warranty applies.