EXHIBIT 150
PART 14

CERTIFICATE

By Authority Of
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Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1155 – 98

An American National Standard

Standard Practice for Selection and Application of Piping System Materials[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 (ε) 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[2]

A 105/A105M Specification for Carbon Steel Forgings for Piping Applications[2]

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service[2]

A 134 Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)[2]

A 139/A 139M Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)[2]

A 178/A 178M Specification for Electric-Resistance Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes[2]

A 179/A 179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes[2]

A 181/A 181M Specification for Carbon Steel Forgings, for General-Purpose Piping[2]

A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service[2]

A 192/A 192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service[2]

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service[2]

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service[2]

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and HeatExchanger Tubes[2]

A 214/A 214M Specification for Electric-Resistance Welded Carbon Steel Heat-Exchanger and Condenser Tubes[2]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service[2]

A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel[4]

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes[2]

A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates[4]

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 Psi Tensile Strength[5]

A 320/A 320M Specification for Alloy Steel Bolting Materials for Low-Temperature Service[2]

A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service[2]

A 351/A 351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts[3]

A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[4]

A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures[3]

A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service[4]

A 536 Specification for Ductile Iron Castings[3]

A 563 Specification for Carbon and Alloy Steel Nuts[5]

B 61 Specification for Steam or Valve Bronze Castings[6]

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[1] This practice 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.

Current edition approved April 10, 1998. Published July 1998. Originally published as F 1155–88. Last previous edition F 1155–88 (1993)[epsilon 1].

[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 15.08.

[6] *Annual Book of ASTM Standards*, Vol 02.01.

B 62 Specification for Composition Bronze or Ounce Metal Castings[6]
B 88 Specification for Seamless Copper Water Tube[6]
B 466 Specification for Seamless Copper-Nickel Pipe and Tube[6]
B 467 Specification for Welded Copper-Nickel Pipe[6]
D 2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[7]
D 2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[7]
D 4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges[7]
F 682 Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings[8]
F 683 Practice for Selection and Application of Thermal Insulation for Piping and Machinery[8]
F 704 Practice for Selecting Bolting Lengths for Piping System Flanged Joints[8]
F 722 Specification for Welded Joints for Shipboard Piping Systems[8]
F 1476 Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications[8]
F 1548 Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings Used in Piping Applications[8]

2.2 *ANSI Standards:*[9]
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.9 Factor Made Wrought Steel Buttwelding Fittings
B16.10 Face to Face and End to End Dimensions of Valves
B16.11 Forged Steel Fittings, Socket Welding and Threaded
B16.15 Cast Bronze Threaded Fittings Class 125 and 250
B16.18 Cast Copper Alloy Solder Joint Pressure Fittings
B16.22 Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
B16.24 Bronze Flanges and Flanged
B16.28 Wrought Steel Buttwelding Short Radius Elbows and Returns
B16.34 Valves Flanged, Threaded and Welding End
B16.42 Ductile Iron Pipe Flanges and Flanged Fittings
B18.2.1 Square and Hex Bolts and Screws Inch Series
B18.2.2 Square and Hex Nuts (Inch Series)
B31.1 Power Piping
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *Manufacturer's Standardization Society of the Valve and Fitting Industry Standards:*[10]
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
SP-83 Carbon Steel Pipe Unions, Socket-Welding and Threaded

2.4 *Other Documents:*
ASME Boiler and Pressure Vessel Code, Sections I and VIII[11]
ABS' Rules for Building and Classing Steel Vessels[12]
Title 46, Code of Federal Regulations, Parts 41 to 69[13]
NVIC 11-86; Guidelines Governing the Use of Fiberglass Pipe (FGP) on Coast Guard Inspected Vessels[13]
MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver-Brazing[13]

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).

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.

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[7] *Annual Book of ASTM Standards*, Vol 08.04.
[8] *Annual Book of ASTM Standards*, Vol 01.07.
[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.
[13] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

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:

5. Keywords

5.1 materials; piping systems; piping systems materials; ship construction; ship design

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TABLE 1 Material Temperature Limitations[A]

Material	Material Specifications	Temperature Limit, °F, max
Corrosion resistant steel	ASTM A 194/A 194M GR[B] 8, 8C, 8T	1200
	ASTM A 194/A 194M GR 8F	800
	ASME SA312 TP[C] 316L	850
	ASME SA312 TP 304L	800
	ASTM A 351/A 351M GR CF3M	850
Chrome-molybdenum steel	ASTM A 182/A 182M GR F6a, F11	1100
	ASTM A 193/A 193M GR B16	1100
	ASTM A 193/A 193M GF B7	1000
	ASTM A 194/A 194 GR 4	900
	ASME SA217 GR WC6	1100
	ASTM A 234/A 234M GR WP11	1100
	ASTM A 335/A 335M GR P11	1100
	ASTM A 387/A 387M	1000
Carbon steel	ASTM A 53 TY[D] S	800[E]
	ASTM A 53 TY E	650
	ASTM A 105/A 105M	800[E]
	ASTM A 106	800[E]
	ASTM A 134 GR 285C (straight seam)	300
	ASTM A 134 GR 285C (spiral seam)	200
	ASTM A 139/A 139M GR B (straight seam)	300
	ASTM A 139/A 139M GR B (spiral seam)	200
	ASTM A 181/A 181M	800[E]
	ASTM A 194/A 194M GR 2H	800
	ASTM A 216/A 216M GR WCB	1000
	ASTM A 234/A 234M GR WPB	800
	ASTM A 307	400
	ASTM A 515/A 515M GR 70	800
Ductile iron	ASTM A 395	650
	A 536	450
Bronze	ASME SB61	550
	ASME SB62	406
Copper nickel alloy	ASME SB466 C70600	600
	ASME SB467 C70600	600
Copper	ASTM B 88 TY K or L	400
	ASME SB75	400
Glass reinforced plastic	ASTM D 2996 GR 1	225
	ASTM D 2997 GR 1	225
	ASTM D 4024 GR 1	225

[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

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 1100°F[A] Remarks/Limitations
Pipe	Seamless	CrMo[B] steel	ASTM A 335/A 335M GR[C] P11	ANSI B36.10	...
Takedown joints	Flanges: weld neck or socket weld	CrMo steel	ASTM A 182/A 182M GR F11	ANSI B16.5	...
Bolting	Bolts/bolt studs	CrMoV[D] steel	ASTM A 193/A 193M GR B16	ANSI B18.2.1	...
	Nuts	CMo[E] steel	ASTM A 194/A 194M GR 4	ANSI B18.2.2	...
Fittings	Flanged	CrMo steel	ASME SA217 GR WC6 or ASTM A 182/A 182M GR F11	ANSI B16.5	...
	Buttweld	CrMo steel	ASTM A 234/A 234M GR WP11	ANSI B16.9 or B16.28	...
	Socket weld	CrMo steel	ASTM A 182/A 182M GR F11	ANSI B16.11	...
Valves: gate, globe, angle, check	Flanged or buttweld	CrMo steel	ASME SA217 GR WC6 or ASTM A 182/A 182M GR F11	ANSI B16.34	Trim group 1[F]
	Socket weld	CrMo steel	ASTM A 182/A 182M GR F6a or GR F11	ANSI B16.34	...

[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

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 775°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY S or E	ANSI B36.10	A 53 GR B TY[C] E Limited to a design pressure of 350 psig. See also Table 1.
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
Bolting	Bolts/bolt studs	CrMo[D] steel	ASTM A 193/A 193M GR B7	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	...
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	...
	Butt weld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 2[E]
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...

[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.

TABLE 4 Steam, Steam Drains, Feed, Condensate, Boiler Blow Sampling and Compounding, and Safety Valve Escape Piping

Item	Type	Style	Material Specification[A]	Design Specification	Maximum Temperature 406°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY S or E	ANSI B36.10	A 53 GR B TY[D] E limited to a design pressure of 350 psig
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Unions: threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or	ANSI B16.5	...
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 3 and 4[E]
	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	...
	Socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.34	...
	Threaded or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[F]	...

[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

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 1100°F[A] Remarks/Limitations
Pipe	Seamless	CrMo steel[B]	ASTM A 335/A 335M GR[C] P11	ANSI B36.10	...
	Plate formed	CrMo steel	ASTM A 387/A 387M	Commercial[D]	...
Takedown joints	Flanges: weld neck or socket weld	CrMo steel	ASTM A 182/A 182M GR F11	ANSI B16.5	...
	Flanges: plate	CrMo steel	ASTM A 387/A 387M	Commercial[D]	...
Bolting	Bolts/bolt studs	CrMoV[E] steel	ASTM A 193/A 193M GR B16	ANSI B18.2.1	...
	Nuts	CMo[F] steel	ASTM A 194/A 194M GR 4	ANSI B18.2.2	...

[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 6 Gas Turbine and Diesel Exhaust Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 775°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY S or E	ANSI B36.10	See Table 1
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Flanges: plate	Carbon steel	ASTM A 515/A 515M GR 70	Commercial[C]	. . .
Bolting	Bolts/bolt studs	CrMo[D] steel	ASTM A 193/A 193M GR B7	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	. . .
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	. . .
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]GR—grade.
[C]Specific Coast Guard and ABS approval required.
[D]CrMo—chromium-molybdenum.

TABLE 7 Fresh Water for Auxiliary Machinery and Engine Cooling

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 240°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B36.10	...
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR1	Commercial[F]	
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Unions: threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	...
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.9 or B16.28	...
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
	Used with gasketed mechanical couplings	Ductile iron	A 536	F 1548	...
Valves	Butterfly wafer or lug type	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 4[I]
	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[I]
	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3 and 4[I]
	Socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.34	Trim group 3 and 4[I]
	Threaded or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 3 and 4[I]
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[I]
Valves: ball	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M or A 181/A 181M	MSS-SP-72	Trim group 3 and 4[I]

[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]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 8 Fresh Water, Hot and Cold Domestic, Air Conditioning, Sanitary

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 240°F[B] Remarks/Limitations
Pipe	Seamless	Copper	ASTM B 88 TY[C] K or L	ASTM B 88	Hard drawn. Must be annealed for pressures greater than 225 psig.
	Filament wound	FGP[D]	ASTM D 2996 GR[E] 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
Takedown joints	Flanges: silbraze	Bronze	ASME SB62	ANSI B16.24	. . .
	Unions: brazed or threaded	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron[I]	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Silbraze	Copper	ASME SB88 TY K or L	ANSI B16.22	. . .
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	. . .
	Used with gasketed mechanical couplings	Bronze	ASTM B 61 or B 62	ASTM F 1476	. . .
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 4[J]
	Butterfly grooved end	Bronze	ASTM B 61 or B 62	. . .	Trim group 4[J]
Valves: gate, globe, angle, check	Flanged or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[K]	Trim group 4[J]
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72	Trim group 4[J]

[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

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 150°F[B] Remarks/Limitations
Pipe	Seamless or welded	CNA[C] 90:10	ASME SB466 or SB467	ASME SB466 or SB467	
	Filament wound	FGP[D]	ASTM D 2996 GR[E] 1	Commercial[F]	See NVIC 11-86[G]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[F]	See NVIC 11-86[G]
Takedown joints	Flanges: brazed	Bronze	ASME SB62	ANSI B16.24	...
	Unions: brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron[I]	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Bronze	ASME SB61 or SB62	ANSI B16.24	...
	Buttweld or welding sleeve	CNA 90:10	ASME SB466 or SB467	810-1385880	...
	Brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
	Used with gasketed mechanical couplings	Bronze CNA	ASTM B 61 or B 62 ASTM B 466 or ASTM B 467	ASTM F 1548 ASTM F 1548	... ...
Valves	Butterfly water or lug	Ductile iron[J] Carbon steel[J]	ASTM A 395 ASTM A 216/A 216M GR WCB or A 105/A 105M	MSS-SP-67	Trim group 6[K]
	Butterfly grooved end	Bronze	ASTM B 61 or B 62	...	Trim group 4[K]
Valves: gate, globe, angle, check	Flanged Brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[L]	Trim group 6[K]

[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]CNA—copper nickel alloy.
[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]Not permitted with CNA piping.
[K]For trim group definition, refer to Table 28.
[L]MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 10 Dry Fire Main, Foam, Sprinkling, Deckwash, Tank Cleaning Piping

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 200°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B36.10	...
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Threaded	Bronze	ASME SB61 or SB62	ANSI B16.15	...
	Used with Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly wafer or lug type	Ductile iron	ASTM A 395	MSS-SP-67	...
	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[E]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[E]
	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[E]
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...
	Flanged or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[F]	...
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[E]

[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 11 Bilge, Clean Ballast, and Pump Priming Piping

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 100°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance weld	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B36.10	...
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	See NVIC 11-86[G]
Takedown joints	Flanges: slip-on or socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Flanges: plate	Steel with NCA[H] facing	ASTM A 283/A 283M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Flanges: adhesive bonded	GRP[I]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Adhesive bonded	GRP[I]	Commercial	Commercial[F]	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly wafer or lug type	Ductile iron	ASTM A 395	MSS-SP-67	...
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		
	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[J]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 3 and 4[J]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3 and 4[J]
	Threaded or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[K]	Trim group 3 and 4[J]
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[J]

[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]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 12 Diesel and Lube Oil System Piping Fuel Oil Filling, Transfer, and Service Suction Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 200°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	. . .
	Filament wound	FGP[D]	ASTM D 2996 GR 1	Commercial[E]	See NVIC 11-86[F]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[E]	See NVIC 11-86[F]
Takedown joints	Flanges: weldneck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Flanges: adhesive bonded	GRP[G]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Adhesive bonded	GRP[D]	Commercial	Commercial[E]	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly wafer or lug	Ductile iron Carbon steel	ASTM A 395 ASTM A 216/A 216M GR WCB or A 105/A 105M	MSS-SP-67	Trim group 4 and 5[H]
	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[H]
Valves: gate, globe, angle, check	Flanged	Ductile iron Carbon steel	ASTM A 395 ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 4 and 5[H]
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	Trim group 3[H]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[H]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]GR—grade.
[C]TY—type.
[D]FGP—fiberglass pipe.
[E]Specific Coast Guard and ABS approval required.
[F]For U.S. flag vessel in addition to classification society requirements.
[G]GRP—glass reinforced plastic.
[H]For trim group definition, refer to Table 28.

TABLE 13 Fuel Oil Service Discharge Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 300°F[A] Remarks/Limitations
Pipe	Seamless	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S	ANSI B36.10	...
Takedown joints	Flanges: weldneck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[D]
Valves: gate, globe, angle, check	Flanged	Ductile iron Carbon steel	ASTM A 395 ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 4 and 5[D] Trim group 3[D]
	Buttweld or socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[D]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]GR—grade.
[C]TY—type.
[D]For trim group definition, refer to Table 28.

TABLE 14 Cargo Oil and Vent Piping and Crude Oil Wash Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 200°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	...
	Filament wound	FGP[D]	ASTM D 2996 GR 1	Commercial[E]	See NVIC 11-86[F]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[E]	See NVIC 11-86[F]
Takedown joints	Flanges: weld neck, socket weld, or threaded	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Flexible couplings	Steel with resilient gasket	Commercial	Commercial[E]	...
	Flanges: adhesive bonded	GRP[G]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Ductile iron	ASTM A 395	ANSI B16.42	...
		Carbon steel	ASTM A 216/A 216M GR WCB	ANSI B16.5	...
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Adhesive bonded	GRP[G]	Commercial	Commercial[E]	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 4[H]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[H]
	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[H]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[H]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[H]
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[H]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]GR—grade.
[C]TY—type.
[D]FGP—fiberglass pipe.
[E]Specific Coast Guard and ABS approval required.
[F]For U.S. flag vessel in addition to classification society requirements.
[G]GRP—glass reinforced plastic.
[H]For trim group definition, refer to Table 28.

TABLE 15 Steering Gear Fill and Drain Piping, and Telemotor Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 406°F[A] Remarks/Limitations
Pipe	Seamless	Copper	ASTM B 88 TY[B] K	ASTM B 88	Must be annealed for pressures over 225 psig
Takedown joints	Unions: brazed or threaded	Bronze	ASME SB61 or SB62	MIL-F-1183	...
Bolting	None required				
Fittings	Brazed or threaded	Bronze	ASME SB61 or SB62	ANSI B16.18	...
	Brazed	Copper	ASME SB75	ANSI B16.22	...
Valves: gate, globe, angle, check	Brazed or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[C]	Trim group[D]
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72, Table 2	Trim group[D]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]TY—type.
[C]MSS-SP-80 valves limited to 75 % of valve design pressure.
[D]For trim group definition, refer to Table 28.

TABLE 16 Hydraulic Piping[A,B]

Item	Type/Style	Material	Material Specification[C]	Design Specification	Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106, A 178/A 178M, A 179/A 179M, A 192/ A 192M or A 214/A 214M	ANSI B36.10	...
		CRES[D]	ASTM A 213/A 213M or A 249/ A 249M		
Takedown joints	Flanges: weldneck or socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: flared, flareless, compression	Carbon steel	Commercial	Commercial[E]	...
Bolting	Bolts/bolt studs	CrMo[F] steel	ASTM A 193/A 193M GR[G] B7	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Flared, flareless, compression	Carbon steel	Commercial	Commercial[E]	...
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 2[H]
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...
	Flared, flareless, compression	Carbon steel	Commercial	Commercial[E]	...
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72	Trim group 3 and 4[H]

[A]This table does not apply to packaged hydraulic systems and equipment. For such applications, specific Coast Guard and ABS approval should be obtained.
[B]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C]When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[D]CRES—corrosion resistant steel.
[E]Specific Coast Guard and ABS approval required.
[F]CrMo—chromium-molybdenum.
[G]GR—grade.
[H]For trim group definition, refer to Table 28.

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TABLE 17 Air Piping 150 psi and Below

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature Ambient[B] Remarks/Limitations
Pipe	Seamless	Carbon steel	ASTM A 106 GR[C] B	ANSI B36.10	...
	Seamless	Copper	ASTM B 88 TY[D] K	ASTM B 88	...
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	See NVIC 11-86[G]
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Unions: brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	...
	Buttweld		ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socketweld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Adhesive bonded	GRP[H]	Commercial[F]	Commercial[F]	...
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	Trim group 3[I]
	Brazed or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 4[I]
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[I]
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72	Trim group 4[I]

[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]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 18 Air Piping Above 150 psi

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature Ambient^A Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR^B B or A 53 GR B TY S or E	ANSI B36.10	A 53 GR B TY^C E limited to a design pressure of 350 psig
Takedown joints	Flanges: weld neck, socket weld, or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	...
	Buttweld		ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling		ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536		Trim group 4^D
Valves: gate, globe, angle, check	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3^D
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4^D
Valves: ball	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M or A 181/A 181M	MSS-SP-72	Trim group 3^D

^{A}Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
^{B}GR—grade.
^{C}TY—type.
^{D}For trim group definition, refer to Table 28.

TABLE 19 Refrigeration Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 406°F^A Remarks/Limitations
Pipe	Seamless	Copper	ASTM B 88 TY^B K or L or ASME SB75	ASTM B 88 or ASME SB75	Must be annealed for pressures over 225 psig
Takedown joints	None				
Bolting	None				
Fittings	Brazed	Copper	ASTM B 88 TY K or L or ASME SB75	ANSI B16.22	...

^{A}Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
^{B}TY—type.

TABLE 20 CO_2, Halon, and Smoke Detection

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 850°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S	ANSI B36.10	See Table 1. Must be internally and externally protected from corrosion. CO_2 piping requires 6000-psig burst rating.
Takedown joints	Flanges: buttweld or socketweld	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
Bolting	Bolts/bolt studs	CrMo[D] steel	ASTM A 193/A 193M GR B7	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	...
Fittings	Buttweld, socketweld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB A 105/A 105M	ANSI B16.9 or B16.28	...
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 2[E]
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...

[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.

TABLE 21 Sounding Tubes, Vents, and Overflows for Freshwater, Saltwater, and Oil

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 406°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B16.10	...
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve couplings		ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536		Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395 A 105/A 105M	ANSI B16.34	Trim group 4[I]
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M		Trim group 3[I]
	Brazed or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 4[I]
	Grooved end	Ductile iron	ASTM A 536		Trim group 3 and 4[I]

[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]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 22 Waste, Soil, and Interior Deck Drains

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 240°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or ASTM A 53 TY[D] S or E	ANSI B36.10	...
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G] FGP not permitted outboard of shell valve.
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	
Takedown joints	Flanges: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded			MSS-SP-83	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
	Sleeve coupling	Carbon steel	ASTM F 682	ASTM F 682	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
	Brazed or threaded	Bronze	ASME SB61 or SB62	ANSI B16.24 MSS-SP-80[J]	Trim group 4[I]
	Grooved end	Ductile iron		ASTM A 536	Trim group 4[I]
Valves: ball	Flanged	Ductile iron	ASTM A 395	MSS-SP-72	Trim group 4[I]
		Bronze	ASME SB61 or SB62		

[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]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 23 Weather Deck Drains, Main Deck, and Above

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature Ambient[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	. . .
Takedown joints	Flanges: socketweld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings		ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[D]
Valves: check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[D]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[D]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[D]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]GR—grade.
[C]TY—type.
[D]For trim group definition, refer to Table 28.

TABLE 24 Inert Gas-Generator or Uptakes to Scrubber

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 840°F[A] Remarks/Limitations
Pipe	Fabricated duct	Alloy steel	ASTM A 242/A 242M TY[B] 1	Commercial[C]	. . .
Takedown joints	Flanges: welded	Alloy steel	ASTM A 242/A 242M TY 1	Commercial[C]	. . .
Bolting	Bolts	CrMoV[D] steel	ASTM A 193/A 193M GR[E] B 16	ANSI B18.2.1	. . .
	Nuts	CMo[F] steel	ASTM A 194/A 194M GR 4	ANSI B18.2.2	. . .
Fittings	Fabricated duct	Alloy steel	ASTM A 242/A 242M TY 1	Commercial[C]	. . .
Valves	Sliding gate	Carbon steel	Commercial[C]	Commercial[C]	Trim group 3[G]
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 3[G]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]TY—type.
[C]Specific Coast Guard and ABS approval required.
[D]CrMoV—chromium-molybdenum-vanadium.
[E]GR—grade.
[F]CMo—carbon-molybdenum.
[G]For trim group definition, refer to Table 28.

TABLE 25 Inert Gas, Scrubber to Tanks

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 406°F[B] Remarks/Limitations
Pipe	Electric resistance welded	Carbon steel	ASTM A 134 GR[C] 285C or ASTM A 139/A 139M GR B	ANSI B36.10	...
	Seamless or electric resistance welded		ASTM A 106 GR B or A 53 GR B TY[D] S or E		
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	
Takedown joints	Flanges: weldneck socket weld or slip-on	Carbon steel	ASTM A 105/A 105M or A 181/A 181M CL 60	ANSI B16.5	...
	Flexible couplings	Steel with resilient gaskets	Commercial	Commercial[F]	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socketweld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve couplings		ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 8[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 8[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
	Flanged, brazed, or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 8[I]

[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]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 26 Liquified Natural Gas Systems Including Vapor Fuel, Inert Gas, and Nitrogen Service

Item	Type/Style	Material	Material Specification	Design Specification	Minimum Temperature 0°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	...
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling		ASTM A 234/A 234M GR WPB	ASTM F 682	...
Valves	Butterfly wafer or lug	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	MSS-SP-67	...
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3[D]
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]GR—grade.
[C]TY—type.
[D]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

Item	Type/Style	Material	Material Specification	Design Specification	Minimum Temperature −325°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	CRES[B]	ASME SA312 TP[C] 316L or 304L	ANSI B36.19	...
Takedown joints	Flanges: weld neck or socket weld	CRES	ASTM A 182/A 182M GR[D] 316L	ANSI B16.5	...
Bolting	Bolts/bolt studs	CRES	ASTM A 320/A 320M GR B8T, B8F, B8M, or B8C	ANSI B18.2.1	...
	Nuts		ASTM A 194/A 194M GR 8, 8C, 8F, or 8T	ANSI B18.2.2	...
Fittings	Buttweld	CRES	ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	ANSI B16.9 or B16.28	...
	Socket weld		ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	ANSI B16.11	...
Valves	Butterfly wafer or lug	CRES	ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	MSS-SP-67	Trim group 7[E]
Valves: gate, globe, angle, check	Flanged, buttweld, or socket weld	CRES	ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	ANSI B16.34	Trim group 7[E]

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]CRES—corrosion resistant steel.
[C]TP—tubular product.
[D]GR—grade.
[E]For trim group definition, refer to Table 28.

TABLE 28 Valve Trim Groups[A]

Group	Trim	Material	Material Specification[B]	Remarks/Limitations
1	Stem	CRES[C]	ASTM A 182/A 182M GR[D]F6a	...
	Wedge/disk	CrMo[E]	ASTM A 182/A 182M GR F11	
	Seat ring	CrMo	ASTM A 182/A 182M GR F11 or ASME SA217 GR WC6	hard-faced seat
	Seat, integral	Same as valve body		
2	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F6a	hard-faced seat
	Integral seats	Same as valve body		
3	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F6a	hard-faced seat optional
	Seat integral	Same as valve body		
4	Stem, wedge/disc or seating	Bronze	ASME SB61 or SB62	...
	Seat integral	Same as valve body		
5	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F6a	...
	Seat integral	Same as valve body		
6	Stem, wedge/disk or seat ring	NCA[F]	ASTM A 164[G]	...
7	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F304L or F316L or ASTM A 351/A 351M GR CF3M	hard-faced seat optional
8	Stem	CRES	ASTM A 182/A 182M GR F6a	...
	Wedge/disk or seat ring	Bronze	ASME SB61 or SB62	...
	Integral seat	Same as valve body	...	...

[A]Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B]When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[C]CRES—corrosion resistant steel.
[D]GR—grade.
[E]CrMo—chromium-molybdenum.
[F]NCA—nickel copper alloy.
[G]Discontinued.

CERTIFICATE

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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Designation: F 1172 – 88 (Reapproved 1998)

An American National Standard

Standard Specification for Fuel Oil Meters of the Volumetric Positive Displacement Type[1]

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]

2.2 *ANSI Standards:*[3]

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:*[4]

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.4 *API Standard:*[5]

Code No. 1101 Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter

2.5 *American Society of Mechanical Engineers:*[6]

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 F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved August 26, 1988. Published December 1988.

[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[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, 345 E. 47th St., New York, NY 10017.

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/mm^2) 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} m^3) 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/mm^2) 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. Quality Assurance Provisions

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

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

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APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1173 – 95

An American National Standard

Standard Specification for Thermosetting Resin Fiberglass Pipe and Fittings to be Used for Marine Applications[1]

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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers machine made reinforced thermosetting epoxy resin pipe and fittings nominal pipe size (NPS) 1 through 48 in. in diameter to be used in marine piping systems in which resistance to corrosion, aging, and deterioration from seawater, gas, chemicals, and sea environment is required.

1.2 When invoked by military or other procurement activities, MIL-P-24608 (SH) shall apply.

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 The dimensionless designator NPS has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 The specific maximum temperature and pressure covered by this specification is 240°F (115.6°C) and 225 psi (15.5 bar).

1.6 The following safety hazards caveat pertains 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:*

D 257 Test Methods for dc Resistance or Conductance of Insulating Materials[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 883 Terminology Relating to Plastics[3]

D 1141 Specification for Substitute Ocean Water[4]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[5]

D 1600 Terminology of Abbreviated Terms Relating to Plastics[3]

D 1898 Practice for Sampling of Plastics[3]

D 2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[5]

D 2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 2924 Test Method for External Pressure Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 2925 Test Method for Beam Deflection of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Under Full Bore Flow[5]

D 2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe[5]

D 2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[5]

D 4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges[5]

D 4496 Test Method for dc Resistance or Conductance of Moderately Conductive Materials[6]

E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Source[7]

E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials[7]

E 800 Guide for Measurement of Gases Present or Generated During Fires[7]

F 412 Terminology Relating to Plastic Piping Systems[5]

2.2 *ANSI Standards:*[8]

B16.1 Cast Iron Pipe Flanges and Flanged Fittings

B16.5 Steel Pipe Flanges, Flanges, Flanged Fittings

2.3 *ISO Standards:*[8]

13 Grey Iron Pipe, Special Castings and Grey Iron Parts for Pressure Main Lines

559 Welded or Seamless Steel Tubes for Water, Sewage and Gas

2.4 *Other Documents:*

[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Feb. 15, 1995. Published April 1995. Originally published as F 1173 – 88. Last previous edition F 1173 – 88 (1993)$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 11.02.

[5] *Annual Book of ASTM Standards*, Vol 08.04.

[6] *Annual Book of ASTM Standards*, Vol 10.02.

[7] *Annual Book of ASTM Standards*, Vol 04.08.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

National Sanitation Foundation Standard 14[9]
MIL-P-24608 (SH) Pipe, Fittings, and Adhesive Kits, Glass Reinforced Thermosetting Epoxy Resin for Shipboard Piping Systems[10]
IMO Assembly Resolution A.753(18)[10]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D 883 or F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *maximum operating pressure*—the highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shut-off pressures, pressure regulating valve lockup (no flow) pressure, and maximum chosen pressure at the system source.

3.2.2 *representative piping system*—a system composed of a single manufacturer's pipes, fittings, joints, and adhesives that would normally be used by a customer or installer. If the system is conductive, any devices normally supplied by the manufacturer (either as electromechanical attachments or integrated into the composite structure) for electrical continuity or grounding are to be included as well.

4. Classification

4.1 *General:*

4.1.1 Pipe meeting this specification is classified by type, grade, and class similar to Classification D 2310.

4.1.2 Fittings meeting this specification are also classified by types (method of manufacture), grades (generic type of resin), and classes (joining system).

4.1.3 Joints meeting this specification are classified only as being conductive or non-conductive.

4.2 *Types:*

4.2.1 *Type I*—Filament-wound (pipe and fittings).

4.2.2 *Type II*—Centrifugally cast (pipe and fittings).

4.2.3 *Type III*—Molded (fittings only).

4.3 *Grades:*

4.3.1 *Grade I*—Epoxy/Epoxy Vinyl Ester resin (pipe and fittings).

4.3.2 *Grade II*—Polyester Resins (pipe and fittings).

4.3.3 *Grade III*—Customer Specified Thermosetting resin (pipe and fittings).

4.4 *Classes:*

4.4.1 *Pipe and Fittings Only:*

4.4.1.1 *Class A*—No liner.

4.4.1.2 *Class B*—Liner, reinforced.

4.4.1.3 *Class C*—Conductive, no liner.

4.4.1.4 *Class D*—Reinforced with conductive outer layer.

4.4.2 *Joining System:*

4.4.2.1 *Class E*—Non-conductive joint.

4.4.2.2 *Class F*—Conductive joint.

4.5 *Piping Systems*, including pipes, joints, and fittings, along with any applicable fire protection coatings or coverings shall meet at least one of the following three levels of full scale fire endurance.

4.5.1 *Level 1*—Piping systems must satisfy the acceptance criteria defined in Annex A4 and pass the fire endurance test method specified in Annex A4 for a duration of a minimum of one h.

4.5.2 *Level 2*—Piping systems must satisfy the acceptance criteria defined in Annex A4 and pass the fire endurance test method specified in Annex A4 for a duration of a minimum of 30 min.

4.5.3 *Level 3*—Piping systems must satisfy the acceptance criteria defined in Annex A5 and pass the fire endurance test method specified in Annex A5 for a duration of a minimum of 30 min.

4.5.4 Piping and insulation systems should not drip during full scale evaluations for levels 1, 2, or 3.

5. Ordering Information

5.1 When ordering pipe and fittings under this specification, the following should be specified:

5.1.1 Designation and date of this specification.

5.1.2 Type.

5.1.3 Grade.

5.1.4 Class.

5.1.5 NPS.

5.1.6 Manufacturer's identification (for example, part number, product's name, etc.).

5.1.7 Specific customer requirements, if any.

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

6.1.2 *Joining Systems*—The joining system used shall be rated for the same design conditions as the pipe and fittings. This includes design for internal pressure, tensile strength, bending strength, electrical resistance, etc., as called for in Section 7.

6.2 *Manufacture:*

6.2.1 Pipe manufactured by the filament winding process shall be in accordance with Specification D 2996.

6.2.2 Pipe manufactured by the centrifugal casting process shall be in accordance with Specification D 2997.

6.2.3 Fittings shall be manufactured by the filament wound, molded, or centrifugally cast process, using thermosetting resin and glass reinforcement.

7. Performance Requirements

7.1 *General:*

7.1.1 The requirements of this section apply to all piping and piping systems independent of service or location.

7.1.2 The specification of the piping shall meet the performance guidelines that follow.

7.1.3 The structural wall of the piping system shall have sufficient strength to take account of the most severe coincident conditions of pressure, temperature, the weight of the piping itself, and any static and dynamic loads imposed by the design or environment. Once the structural wall

[9] Available from the National Sanitation Foundation, 3475 Plymouth Rd., P.O. Box 1460, Ann Arbor, MI 48106.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

thickness is calculated, the corrosion liner is added to obtain the pipe's total wall thickness.

7.1.4 For the purpose of assuring adequate robustness for all piping systems, including open-ended piping, all pipe, fittings, and joints shall have a minimum structural wall thickness able to withstand loads due to transportation, handling, installation, personnel traffic, etc. This may require the pipe, fittings, and joints to have additional structural thickness than otherwise required by service considerations.

7.1.5 The performance requirements for any component of a piping system such as fittings and joints are the same as those requirements for the piping system they are installed in.

7.2 *Hydrostatic Strength:*

7.2.1 A piping system shall be designed for a maximum operating pressure not less than the maximum working pressure to be expected under operating conditions nor less than the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

7.2.2 The maximum operating pressure for a pipe system shall be determined by dividing the short-term hydrostatic test failure pressure by a minimum safety factor of 4 or the long-term hydrostatic (>100,000 hours) test failure pressure by a minimum safety factor of 2.5, whichever is the lesser of the two. Special design cases, such as where pressure surges can not be accurately estimated or where dynamic loads cannot be accurately accounted for, may warrant safety factors in excess of these values, in some cases as great as 10:1. Either the short-term or the long-term hydrostatic test pressures, whichever is used, shall be verified experimentally or by a combination of testing and calculations to the satisfaction of the approving authority. In all designs, the maximum allowable internal pressure shall be based on the weakest part of the system, be it the pipe, fittings, and flanges or the joining method used.

7.2.2.1 The maximum operating pressure shall be based on the structural wall thickness, not the total wall thickness.

7.3 *External Pressure:*

7.3.1 External pressure shall be taken into account in the design of the piping system for any installation which may be subject to vacuum conditions inside the pipe or a pressure head acting on the outside of the pipe.

7.3.2 A piping system shall be designed for a maximum allowable external pressure not less than the sum of the maximum potential pressure head outside the pipe plus the design vacuum pressure. The maximum allowable external pressure for a piping system shall be determined by dividing the collapse test pressure by a minimum safety factor of 3. Special design cases, such as where pressure surges cannot be accurately estimated or where dynamic loads cannot be accurately accounted for, may warrant safety factors in excess of these values, in some cases as great as 10:1. The collapse test pressure shall be verified experimentally or by a combination of testing and calculation methods to the satisfaction of the approving authority.

7.3.2.1 The maximum allowable external pressure shall be based on the structural wall thickness, not the total wall thickness.

7.4 *Longitudinal Tensile Properties:*

7.4.1 The sum of the longitudinal stresses due to pressure, weight and other dynamic and sustained loads shall not exceed the maximum allowable stress in the longitudinal direction. Forces due to thermal expansion, contraction, and external loads, such as wind loads, seismic loads, etc., shall be considered when determining longitudinal stresses in the system. Internal shock, or pressure surge, commonly known as water hammer, shall also be considered when determining the stresses in the system.

7.4.2 The sum of the longitudinal stresses shall not exceed half of the nominal circumferential stress derived from the nominal internal pressure determined according to 2.2, unless the maximum allowable longitudinal stress is verified experimentally or by a combination of testing and calculation methods to the satisfaction of the approving authority.

7.4.2.1 The maximum allowable maximum longitudinal stress shall be based on the structural wall thickness, not the total wall thickness.

7.5 *Bending Strength:*

7.5.1 A piping system shall be designed for a maximum allowable bending stress not less than the sum of all bending stress due to dead weight, expansion loads, external loads, and any other static or dynamic loads imposed on the piping system.

7.5.2.1 The maximum allowable maximum bending stress shall be based on the structural wall thickness, not the total wall thickness.

7.6 *Beam Stiffness:*

7.6.1 The piping system shall be supported properly to limit the vertical deflection in any part of the piping system to 0.5 in. (12.7 mm).

7.6.2 The calculation of support spacing shall take into account the dead weight of the pipe and its fluid contents as well as any other static external loads.

7.6.2.1 The maximum allowable maximum support spacing shall be based on the structural wall thickness, not the total wall thickness.

7.7 *Temperature:*

7.7.1 The piping system shall meet the design requirements of these guidelines over the range of service temperatures it will experience.

7.7.2 The maximum working temperature should be at least 36°F (20°C) less than the minimum heat distortion temperature (determined according to ISO 75 method A, or equivalent) of the resin or plastic material. The minimum heat distortion temperature should not be less than 176°F (80°C).

7.7.3 Where high or low temperature services are encountered, special attention should be paid to material properties. Material properties such as strength, modulus, etc., will change with temperature, therefore, they shall be modified according to the pipe system's design temperature.

7.8 *Impact Resistance:*

7.8.1 A piping system shall have a minimum resistance to impact to the satisfaction of the approving authority. The impact resistance needs to satisfy all impact loading due to transportation and installation, not just under normal operation.

7.9 *Ageing:*

7.9.1 Before selection of a piping system material, the manufacturer shall confirm that the environmental effects including, but not limited to, ultraviolet rays, saltwater exposure, oil and grease exposure, temperature, and humidity, will not degrade the mechanical, electrical, or physical properties of the piping system material below the values necessary to meet these guidelines.

7.10 *Fatigue:*

7.10.1 In the cases where design loadings incorporate a significant cyclic or fluctuating component, fatigue shall be considered in the material selection process and taken into account in the installation design.

7.10.2 In addressing material fatigue, the designer may rely on experience with similar materials in similar service or only laboratory evaluation with mechanical test specimens. However, the designer is cautioned that small changes in the material composition may significantly affect fatigue behavior.

7.11 *Erosion Resistance:*

7.11.1 In the cases where fluid in the system has high flow velocities, abrasive characteristics, or where there are flow path discontinuities producing excessive turbulence, the possible effect of erosion shall be considered. If erosion can not be avoided then adequate measures shall be taken such as special liners, change of materials, etc.

7.12 *Fluid Absorption:*

7.12.1 Absorption of fluid by the piping system material shall not cause a reduction of mechanical, electrical, or physical properties of the material below that required by these guidelines.

7.13 *Material Compatibility:*

7.13.1 The piping material shall be compatible with the fluid being carried or in which it is immersed such that its design strength does not degenerate below that recognized by these guidelines. Where the reaction between the pipe material and the fluid is unknown, the compatibility should be demonstrated to the satisfaction of the approving authority.

7.14 *Potable Water Usage:*

7.14.1 The material, including pipe, fittings, and joints shall have no adverse effect on the health of personnel when used for potable water service. The material used for such purposes shall be to the satisfaction of the authority.

7.15 *Electrical Resistance*—Classes C and D pipe and fittings, and F joints and representative systems assembled from such components shall have a resistance per unit length not to exceed 1×10^5 Ω/meter (3.281×10^5 Ω/foot) when tested in accordance with 11.12.

7.16 *Static Charge Shielding*—Classes C and D pipe and fittings and F joints shall have a maximum resulting voltage not to exceed 100 V induced on the exterior surface of the pipe when tested in accordance with 11.13.

7.17 *Grounding Resistance*—Resistance to ground should not exceed 1×10^6 Ω when tested in accordance with 11.14.

7.18 *Flame Spread*—Piping shall have a flame spread index of 25 or less when tested in accordance with 11.9. Nominal 6-inch pipe should be cut into three 2-inch by 18-inch sections, measured along its chord and axially, respectively (19.5°) to approximate the flat 6 inch by 18 inch panel required in Test Method E 162. Edges of each of these sections should be cut so that they are completely flush (0.001″ gap maximum) to each other along the entire length of the sections. Where protective coatings or coverings are used, they shall also be tested while coated on or attached to the pipe sections. The outer surface should be orthogonal to the fire direction. The IMD Assembly Resolution A.753(18) is an alternative test method.

7.19 *Smoke Generation*—The maximum specific optical density under uncorrected flaming and nonflaming conditions for pipe should be 200 when tested in accordance with 11.10. 3 in. by 3 in., measured axially and along its chord (29° segment), square pieces should be cut from 12 in. pipe. Where protective coatings or coverings are used, they shall also be tested while coated or attached to the pipe sections. The outer surface should be orthogonal to the fire direction.

7.20 *Toxic Products of Combustion*—The following gases should have concentrations less than or equal to the limits listed in Table 1 when measured in accordance with Guide E 800 or equivalent during smoke generation (test 3). Samples should be drawn from the smoke chamber either at the point of maximum smoke concentration, or at the end of the test. The point of maximum smoke concentration, or at the end of the test. The point of maximum smoke concentration is explained in Guide E 800. For purposes of sampling, it may be defined as the point in time up to two minutes after the smoke concentration begins to decline or flatten out in a straight line. Burning of the pipe samples shall be done with Test Method E 662.

8. Other Requirements

8.1 *Flanges*—Fiberglass flanges for merchant vessels shall conform to Specification D 4024, ANSI B16.1, and ANSI B16.5.

8.2 *Potable Water Piping Systems*—Fiberglass pipe and fittings to be used on potable water systems must conform with National Sanitation Foundation Standard 14.

8.3 *Conductive Systems and Components:*

8.3.1 Conductive pipes, fittings, and joints meeting this specification and systems constructed thereof are preferred to be homogeneously conductive throughout.

8.3.2 Conductivity may be achieved through the use of conductive layers. In this case, the following applies:

8.3.2.1 Two conductive layers, as a minimum, are required—one on the interior and one on the exterior.

8.3.2.2 Conductive connections between the layers are required to equalize potential between the layers. The resistance of these connections shall meet the requirements of 7.15 and 7.17.

8.3.2.3 Test points must be included that are easily accessible on the exterior surface to permit measurement of the interior layer's resistance per unit length after installation. These test points must be electrically isolated from the exterior conductive layer.

8.3.2.4 The internal and external conductive layers, con-

TABLE 1 Gas Concentrations

Gas	Maximum Concentration (PPM)
CO	500
CO_2	15,000
HCl	20
HF	8
HCN	10
SO_2	10
NO_x	5
NH_3	200
$COCl_2$	1
H_2S	15

ductive connections, and test points shall be suitable for the system's intended service and have a lifetime expectation no less than the non-conductive materials of the system.

9. Dimensions and Tolerances

9.1 Dimensions and tolerances of pipe and fittings shall meet the requirements of Annex A6, unless otherwise agreed upon by the buyer and seller.

10. Workmanship, Finish, and Appearance

10.1 The pipe and fittings shall be free from defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, cracks, porosity, and resin-starved areas which, due to their nature, degree, or extent, detrimentally affect the strength, serviceability, and conductivity (as applicable) of the pipe and fittings. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. The pipe and fittings shall be smooth and uniform. All pipe and fittings ends shall be cut at right angles to the axis of the pipe and any sharp edges removed. The bore of each fitting shall have a smooth uniform surface, and protrusion exceeding 1⁄16 in. (1.6 mm) of material into the internal fittings flow area shall be removed and blended with adjacent smooth surfaces.

11. Test Methods

11.1 *Conditioning*—Condition test specimens at 73 ± 4°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 48 h prior to testing, in accordance with Procedure A of Practice D 618, for those tests in which conditioning is required and in all cases of disagreement.

11.2 *Test Conditions*—Conduct tests at ambient temperature and humidity, unless otherwise specified in the test method or in this specification.

11.3 *Sampling*—To determine conformance of the material to the hydrostatic strength requirements of 7.2, take samples of pipe at random on a monthly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with accepted statistical practice.

11.4 *Dimensions and Tolerances*—Determine wall thickness, length, diameter, and liner thickness in accordance with Practice D 3567.

11.5 *Hydrostatic Strength*—Determine hydrostatic strength in accordance with Test Method D 1599 (free ends test).

11.6 *Impact Resistance*—Determine impact resistance in accordance with the recommended test method in Annex A1.

11.7 *Beam Stiffness*—Test the pipe samples at a minimum temperature of 240°F (116°C) in accordance with Test Method D 2925. After determining *EI* from the test results, calculate the permissible simple span for ½ in. (25 mm) deflection. The calculated span after 1000 h at 240°F (116°C) shall not be less than those given by the manufacturer's literature, assuming the pipe to be full of water.

11.8 *External Pressure Resistance*—Test the pipe samples at 240°F (116°C) in accordance with Test Method D 2924. The failure pressure for the manufacturer's minimum wall thickness shall not be less than three times the rate of external pressure resistance published by the manufacturer's product specifications. Calculate the failure pressure for all pipe sizes of identical construction using the following equation:

$$P = \frac{8K't^3}{(OD - t)^3}$$

where:

P = pressure at collapse or leak, psi (kPa),
K' = KE, psi (kPa),
K = buckling scaling constant determined by Test Method D 2924,
E = circumferential modulus of elasticity as defined in Test Method D 2924,
t = minimum reinforced wall thickness, in. (mm), and
OD = outside diameter of pipe, in. (mm).

11.9 *Flame Spread*—Test samples cut from pipe in accordance with 7.18 and tested per Test Method E 162 or equivalent.

11.10 *Smoke Generation*—Test samples cut from pipe in accordance with 7.19 and tested per Test Method E 662 or equivalent.

11.11 *Toxic Products of Combustion*—Determine the toxic products of combustion during smoke generation test 3 of Test Method E 800 or equivalent.

11.12 *Electrical Resistance Per Unit Length*—Determine electrical resistance in accordance with the recommended test method in Annex A3.

11.13 *Static Charge Shielding Capability*—Determine static charge shielding capability in accordance with the recommended test method in Annex A2.

11.14 *Grounding Resistance*—Determine grounding resistance in accordance with the recommended test method in Annex A2.

11.15 *Longitudinal Tensile Properties*—Determine longitudinal tensile properties in accordance with Test Method D 2105.

12. Inspection and Sampling

12.1 Inspection and sampling of the material shall be in accordance with Practice D 1898 and agreed upon between the purchaser and the supplier as part of the purchase contract.

13. Certification

13.1 *General:*

13.1.1 A producer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be furnished.

13.2 If the supplier has in his possession bonafide test certification data acceptable to the purchaser, the purchaser may extend initial approval under 13.1 of this specification.

14. Product Marking

14.1 Pipe and fittings shall be marked with the name, brand or trademark of the manufacturer, NPS, weight (type, grade, and class), specification designation, and date and any other information that may be desired for a specific material.

15. Keywords

15.1 epoxy resin fittings; epoxy resin pipe; marine piping; nominal pipe size; thermoset epoxy resin pipe

ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR IMPACT RESISTANCE OF FIBERGLASS PIPE AND FITTINGS BY MEANS OF A FALLING STEEL BALL

A1.1 Scope

A1.1.1 This test method covers the determination of the energy required to produce failure in fiberglass pipe and fittings under specified conditions of impact by means of a falling steel ball. Balls of differing diameter and weight may be used.

A1.2 Significance

A1.2.1 The testing procedures in this test method are applicable over a range of impact energies and ball diameters. The specific ball weight and diameter must be selected for each size and type of product.

A1.2.2 This test method is intended to represent service conditions wherein the product may be subjected to damage from impact by falling objects such as tools. Low-velocity impact, such as that caused by dropping a full length of pipe or fitting for a small distance onto a support surface, may not be accurately represented by this test method.

A1.3 Apparatus

A1.3.1 *General*—One type of impact tester is illustrated in Fig. A1.1.

A1.3.2 *Steel Ball*—Two different balls may be used. The ball designated A is 2.30 in. (58.4 mm) in diameter with a weight of 29.15 oz (826.5 g). The ball designated B has a diameter of 3.00 in. (76.2 mm) and a weight of 63.5 oz (1800 g). Other ball sizes may be used upon agreement between the buyer and the seller.

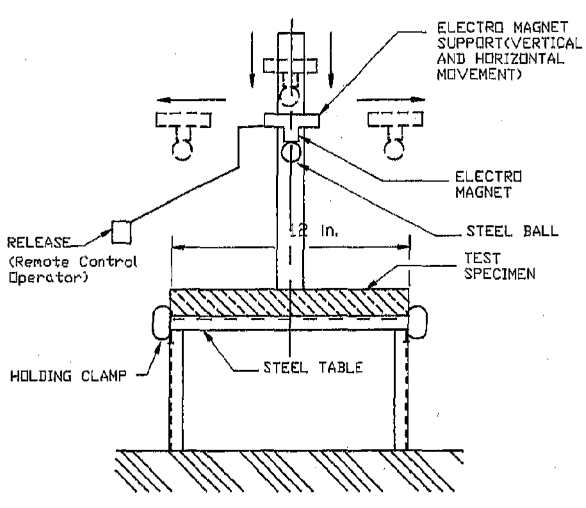


FIG. A1.1 Test Apparatus

A1.3.3 *Support Surface*—The test stand from which the ball is dropped shall be resting firmly on a concrete slab floor.

A1.3.4 *Vertical Drop*—A plump bob shall be used to ensure that the ball will drop squarely on the test specimen when released.

A1.3.5 Drop heights in increments of 1, 2, or 3 in. (25.4, 51, or 76 mm) are normally used. Means shall be provided to hold the ball at the appropriate drop heights above the test specimen as measured from the bottom of the ball to the surface of the specimen, to release the ball in a reproducible manner and to allow the ball to fall freely. Mechanical means may be used to catch the rebounding ball, or it may be caught by hand.

A1.3.6 *Specimen Holder:*

A1.3.6.1 For testing pipe, the specimen shall rest for its full length on a flat steel plate at least 0.5 in. (13 mm) thick.

A1.3.6.2 For testing fittings, a steel saddle plate curved to fit the part may be required to produce line bearing, as, for example, when the ball is being dropped onto the outer radius of a 90° elbow.

A1.3.6.3 Means shall be provided to clamp the specimen firmly into proper position at each end.

A1.4 Test Specimens

A1.4.1 The test specimens of pipe shall be equal in length to the nominal diameter but not less than 12-in. (305-mm) long. If impact resistance can vary along the pipe length, select test specimens from at least three widely spaced locations.

A1.4.2 Fittings shall be tested as a single unassembled unit.

A1.5 Number of Specimens

A1.5.1 The approximate starting point can usually be determined on one preliminary specimen.

A1.5.2 Sufficient specimens shall be used thereafter to produce a minimum of four drops at each of three different drop heights. Usable data are obtained only when, at a given drop height, at least one drop causes a failure and at least one drop does not cause a failure. If usable data are obtained at only one or two of the selected drop heights, reduce the drop height increments and continue testing within the range of heights yielding usable data.

A1.6 Conditioning

A1.6.1 The test specimens shall be conditioned at 73° + 4°F (23° + 3°C) for a minimum of 8 h prior to testing for those tests in which conditioning is required.

A1.6.2 Tests made at other temperatures shall be made in an enclosure maintained at the test temperature.

A1.7 Procedure

A1.7.1 Measure the dimensions of the test specimens in accordance with Practice D 3567. Include measurements of liner thickness and external coating thickness if applicable.

A1.7.2 Mount the specimen so the ball will strike no less than 3 in. (76 mm) from its end. The point of impact shall be at the top of the vertical diameter. Mark the point of impact and drop height on the outside of the specimen with a marking pen.

A1.7.3 Make preliminary tests to determine the approximate height of fall to produce failure in the particular pipe or fitting being tested. At this point it will usually not be necessary to cut the specimen in order to examine the inside surface.

A1.7.4 Select a ball weight and size that will produce failures between NPS 6 and 60. Using additional specimens test at three different drop heights that bracket the approximate height determined previously.

A1.7.5 Pipe less than NPS 2 in diameter are impacted twice at diametrically opposite points. Pipe NPS 2 or more in diameter can be impacted at each cross section a minimum of four times equally spaced around the circumference, using equal drop heights. As permitted by specimen diameter, additional drop points may be used with a circumferential spacing of 3 in. (76 mm). With a specimen 12 in. (305 mm) in length, drops may be made at three different cross sections (at the quarter points).

A1.7.6 For testing fittings, use diametrically opposite drop points or points in a line separated by a minimum of 3 in. (76 mm), depending on specimen geometry. For example, a 90° elbow may be laid on its side and tested at diametrically opposite points every 3 in. (76 mm) along its length, or it may be supported on a curved saddle plate and tested at points every 3 in. (76 mm) along its outer radius.

A1.7.6.1 Impact resistance of certain fittings will be a function of the fitting geometry at the point of impact. For example, testing on a 90° elbow may be limited to drops only on the outside radius when the test results reveal this as the critical area.

A1.7.7 A minimum of four impacts at each of three different drop heights which produce usable data are required (see A5.2).

A1.7.8 After a specimen has been impacted in as many places as permitted herein, cut the specimen lengthwise along its axis to examine the inside surface for failure. If a leakage test is to be performed on the impacted specimen, this can be carried out using water or air prior to cutting. The test pressure shall be 1½ times the rated pressure for the part.

A1.7.9 Swab the inside surface with fluorescent dye and use an ultraviolet light to detect failure. As an alternative, it may be possible to use other dyes or inks to high-light cracks.

A1.8 Definition of Failure

A1.8.1 Failure in the test specimen shall be shattering or any crack or split on the inside that was created by the impact which, when highlighted with dyes or inks, can be seen by the naked eye.

A1.8.2 Leaking of the specimen as a result of impact shall also be defined as failure. Because of difficulty in observing damage on the inside, failure in an unlined pipe or fitting will normally be defined as leakage in a pressure test.

A1.8.3 Damage to an external coating is not considered failure unless agreed upon between the buyer and the seller.

A1.9 Determination of Average and Standard Deviation

A1.9.1 Calculate the percentage of failures at each drop height.

A1.9.2 Plot the percentage of failures versus drop height on probability paper and draw a best-fit line representing the trend of the data. Read off the mean drop height, h_{50}, and drop height standard deviation $h_{50} - h_{15.9}$.

A1.9.3 Calculate the impact resistance as ball weight in pounds (newtons) times drop height in feet (meters). Calculate the standard deviation of impact resistance as ball weight times drop height standard deviation.

A1.10 Report

A1.10.1 Report the following information:

A1.10.1.1 Complete identification of the pipe or fitting tested including manufacturer's name and code, NPS, and average wall, liner, and coating thicknesses.

A1.10.1.2 Location of test specimens along pipe length, if applicable.

A1.10.1.3 Atmosphere in which the test was made and conditioning procedure.

A1.10.1.4 Ball diameter and weight.

A1.10.1.5 Average impact resistance in ft·lbf (N·m).

A1.10.1.6 Standard deviation in ft·lbf (N·m).

A1.10.1.7 Point of impact on fittings.

A1.10.1.8 Mode of failure (visible crack or leak) and appearance of impact area.

A1.10.1.9 Results of pressure test if applicable.

A1.10.1.10 Date of test.

A2. TEST METHOD FOR DETERMINING THE STATIC CHARGE SHIELDING CAPABILITY AND SYSTEM RESISTANCE OF REINFORCED THERMOSETTING RESIN PIPE, FITTINGS, AND JOINTS AFTER EXPOSURE TO VARIOUS CHEMICAL ENVIRONMENTS

A2.1 Scope

A2.1.1 This test method determines the static charge, if any, present on the exterior surface of a grounded fiberglass pipe, fitting, or joint when a charge is applied to the interior surface. It is also used to measure the resistance of the associated grounding techniques and to determine the effect of typical chemical exposures on the shielding capability of the pipe and grounding system.

A2.2 Summary of Test Methods

A2.2.1 *Grounding Resistance*—The test method consists of electrically isolating the pipe, fitting, or joint, then grounding the system using its associated grounding technique, and measuring the resistance of the system from an interior surface to a common ground,

A2.2.2 *Static Charge Shielding Capability*—This test method consists of applying a static charge to the interior

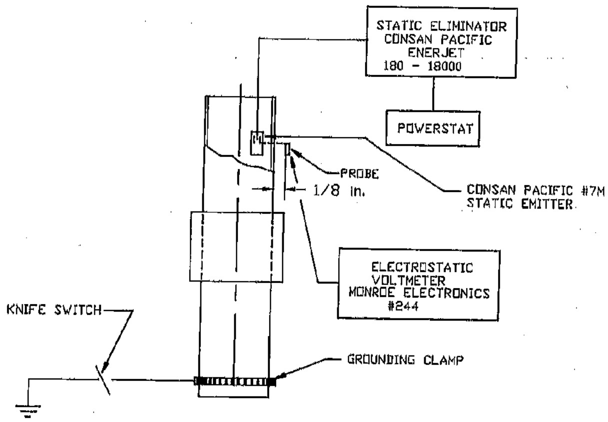


FIG. A2.1 Test Setup

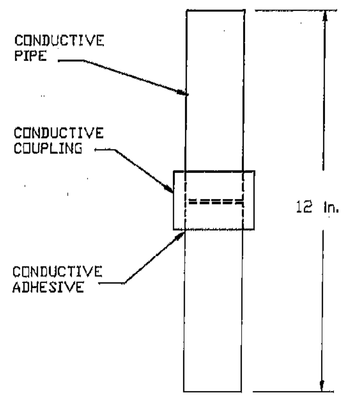


FIG. A2.2 Test Specimens

surface of a grounded reinforced thermosetting resin pipe, fitting, or joint and then measuring the resulting voltage, if any, induced on the exterior surface.

A2.3 Test Equipment (see Fig. A2.1)

A2.3.1 *Static Generator*—An instrument capable of producing clouds of either negative or positive charges having a controlled voltage of 0 to 1000 V.[11]

A2.3.2 *Electrostatic Voltmeter*—An electrostatic voltmeter having a range of 0 to +3000 V and an accuracy of 0.1 %.[12]

A2.3.3 *Exposure Tank*—An exposure tank of nonmetallic construction and resistant to the test environment. It shall be maintained at a temperature of 60 to 80°F (15.6° to 26.7°C) throughout the duration of the test.

A2.3.4 *Oven*—An oven capable of being controlled to a temperature of 150° + 10°F (65.6° + 10°C).

A2.3.5 *Megohmmeter*—A megohmmeter having an accuracy of ±2 %.

A2.4 Test Specimens (see Fig. A2.2)

A2.4.1 *Specimen Size:*

A2.4.1.1 *Diameter*—Unless otherwise specified, the nominal diameter of the pipe, fitting, or joint tested shall be 2 in. (Fig. A2.2).

A2.4.1.2 *Length*—The length of the specimen shall be a minimum of seven times the nominal diameter of the pipe. To achieve this length, additional sections of conductive pipe shall be added as necessary, using the manufacturer's normally recommended assembly methods. If the additional sections are needed, resistance measurements shall be taken across the joints to ensure that the resistance per unit length does not exceed 1×10^5 ohms per meter (3.281×10^5 ohms per foot). The procedures in Annex A3 shall be used.

A2.5 Conditioning

A2.5.1 No special conditioning of the samples prior to initiation of the test is required.

A2.6 Procedure

A2.6.1 Apply a suitable paint-on electrode around the interior circumference of the specimen on the end to which the grounding system will be installed. The distance of the electrode from the end of the specimen shall be greater than or equal to twice the specimen thickness. The width of the electrode shall be greater than four times the specimen wall thickness. Dimensional tolerances of the electrode with and its distance to the end shall not exceed ±10 % separately or combined. Allow the electrode to dry, then install the grounding clamp of the ground system on the exterior of the specimen at one end in accordance with the manufacturer's instructions. Any surface preparation shall not exceed that normally required when assembling a piping system using a fitting. If it is desired to compute surface or volume resistivity, then the procedures in Test Methods D 257 and D 4496 shall be adhered to.

A2.6.2 Position the specimen vertically on a nonconducting surface. Ground the specimen through the grounding system, and using the megohmmeter measure the resistance of the ground system from ground to a position on the interior surface of the electrode. The power applied should neither exceed 1W, nor should the electrification time exceed one min unless otherwise specified. Record the reading of the megohmmeter and its accuracy at that range.

A2.6.3 Thoroughly remove the electrode, then lower the static emitter into the interior of the pipe, fitting, or joint so that it is equidistant from each end. The emitter must be located as close to the interior surface of the pipe, fitting, or joint as possible.

A2.6.4 Approximately ⅛ in. (3.2 mm) from the exterior surface of the pipe, fitting or joint, and opposite the static emitter, position the probe from the electrostatic voltmeter. Fig. A2.1 shows a typical test setup.

A2.6.5 With the specimen ungrounded, turn the static eliminator on and adjust its output via a powerstat to obtain a voltage reading of 2500 permissible deviation (for example, +10 V) on the electrostatic voltmeter.

A2.6.6 Ground the test specimen by closing a switch connecting the test specimen to ground and record the residual voltage.

A2.6.7 If the effect of a chemical on the shielding charac-

[11] A Static Eliminator has been found to meet these requirements.

[12] An instrument manufactured by Monroe Electronics, Model No. 244, has been found to meet this requirement.

teristics of the pipe, fitting, or joint and grounding technique is being studied, place the test specimen in a test tank so that it is completely immersed in the test fluid after initial measurement. Maintain the temperature of the bath at 60° to 80°F (15.6° to 26.7°C) throughout the duration of the test. Suggested test environments include but are not limited to (*1*) salt water per Specification D 1141, (*2*) gasoline, (*3*) Bunker C, and (*4*) 1 % sulfuric acid.

A2.6.8 At the end of 1, 3, 6, and 12 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.

A2.6.9 Wipe dry and place the test specimen in an oven at 150 + 10°F for a period of 2 h.

A2.6.10 At the end of 2 h, remove the specimen from the oven and allow it to cool to 70° to 80°F (21.1° to 26.7°C) in a 50 ± 5 % relative humidity environment for 60 ± 5 min before retesting.

A2.6.11 Repeat A2.6.1 through A2.6.6.

A2.6.12 Note the appearance of the test specimens and the condition of the grounding clamp.

A2.7 Report

A2.7.1 Report the following information:

A2.7.1.1 Manufacturer of pipe, fitting, or joint.

A2.7.1.2 Designation of product being tested.

A2.7.1.3 Description of the test sample including diameter of pipe, fitting, or joint and lengths of pipe extenders (when needed).

A2.7.1.4 Description of grounding details.

A2.7.1.5 Initial resistance reading of grounding system and accuracy and those before and after exposure periods of 1, 3, 6, and 12 months when the exposure periods are used.

A2.7.1.6 Test media.

A2.7.1.7 Initial exterior voltage readings before and after grounding and the exterior voltage reading before and after grounding following exposure periods of 1, 3, 6, and 12 months when the exposure periods are used.

A2.7.1.8 Appearance of test specimen.

A2.7.1.9 Date of test.

A3. TEST METHOD FOR DETERMINING THE ELECTRICAL RESISTANCE PER UNIT LENGTH OF FIBERGLASS PIPE, FITTINGS, AND JOINTS AND REPRESENTATIVE PIPING SYSTEMS AFTER EXPOSURE TO VARIOUS CHEMICAL ENVIRONMENTS

A3.1 Scope

A3.1.1 This test method covers the determination of the electrical resistance per unit length of conductive pipe, fittings, and joints in air before and after exposure to various chemical environments and the electrical resistance per unit length in air of a representative piping system assembled from such components. The components and systems are hereafter referred to in this Annex as the specimen.

A3.2 Summary of Test Method

A3.2.1 In this test method, the length of the potential current path is measured and then a potential difference of 1500 V is applied across the test specimen and a resistor of known value, which are connected in series. The voltage drop across the test specimen is then accurately measured and the resistance of the specimen calculated followed by calculation of resistance per unit length. Figure A3.1 shows a drawing of a typical test setup.

A3.3 Significance

A3.3.1 This test method is suitable for measuring resistance between 2 and 1×10^{10} Ω using an applied voltage of 1500 V.

A3.4 Test Equipment

A3.4.1 *Exposure Tank*—An exposure tank of nonmetallic construction and resistant to the environment being tested. It shall be maintained at a temperature of 60° to 80°F (15.6° to 26.7°C) throughout the duration of the test.

A3.4.2 *Oven*—An oven capable of being controlled to a temperature of 150° ± 10°F (66.6 ± 10°C).

A3.4.3 *Voltmeter*—A voltmeter capable of measuring dc voltages between 0.0001 and 1500 V with a resolution of 0.005 %.[13]

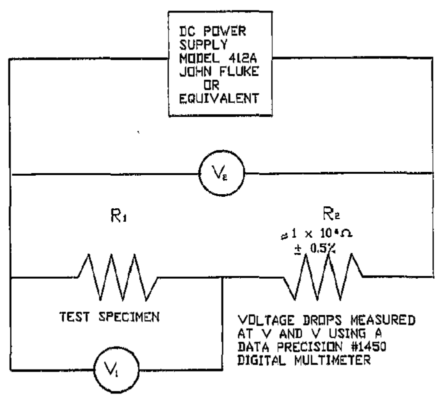


FIG. A3.1 Test Setup for Determining the Electrical Resistance of Fiberglass Pipe and Fittings

A3.4.4 *dc Power Supply*—A constant voltage dc power supply capable of supplying 1500 V at a current of 0.5 mA.

A3.4.5 *A 1* × *10*[6] ± 0.5 % × 1 watt resistor.

A3.5 Test Specimens

A3.5.1 *Pipe, Fittings, and Joints:*

A3.5.1.1 *Diameter*—Unless otherwise specified, the nominal diameter of the pipe, fitting, or joint tested shall be 2 in.

A3.5.1.2 *Length*—The length of the specimen shall be six times the nominal diameter of the product plus two times the width of the grounding clamps. To achieve this length,

[13] A Data Precision Model No. 1450 Digital Multimeter has been found satisfactory for this purpose.

additional sections of conductive pipe shall be added using the manufacturer's normally recommended assembly methods.

A3.5.2 *Representative Piping Systems:*

A3.5.2.1 *Diameter*—Unless otherwise specified the nominal diameter of the system tested shall be 2 inches.

A3.5.2.2 *Length*—The minimum length shall meet the requirements of A3.5.1.2.

A3.6 Conditioning

A3.6.1 No special conditioning of the specimens prior to initiation of the test is required.

A3.7 Procedure

A3.7.1 *Potential current path selection:*

A3.7.1.1 *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.

A3.7.1.2 *Elbows*—Two path lengths shall be established, one on the outer and one on the inner radius of curvature.

A3.7.1.3 *Crosses*—Six path lengths shall be established, one parallel to each of the longitudinal centerline axes and one along the shortest path from adjacent openings through each 90° bend.

A3.7.1.4 *Tees*—One path shall parallel the centerline axis opposite the interior opening. Two additional paths shall also be established, one along the shortest path from adjacent openings through each 90° bend.

A3.7.1.5 *Laterals*—Three paths shall be established, one parallel to the longitudinal centerline axis, one along the shortest distance between adjacent openings through the oblique angle, and one along the shortest distance between adjacent openings through the obtuse angle.

A3.7.1.6 *Representative piping systems*—The path length shall encompass the longest possible length that parallels the centerline axis of the system.

A3.7.1.7 If extenders are used, both lengths shall incorporate that portion of the extenders needed to meet specimen length requirements.

A3.7.1.8 For components and systems achieving conductivity through use of conductive layers, the resistance per unit length will be measured as follows:

(*a*) Separately through each conductive layer using the path selection criteria in paragraphs A3.7.1.1 through A3.7.1.7.

(*b*) Through the conductive connections between layers. The path length shall consist of the distance between the clamps plus the thickness of the non-conductive portion of the pipe, fitting, or joint. The path shall be measured from the interior of one end through the joint to the exterior of the opposite end.

(*c*) From the exterior part of the test point separately to the interior of each end of the pipe, joint, or fitting.

A3.7.2 *Sample Preparation*—Install the grounding clamps for each potential current path of interest in accordance with the manufacturer's recommendations. In the case of pipes having conductive layers, the recommendations will include methods/equipment that accommodate the separate resistance measurements of inner and outer conductive layers, conductive connections between layers, and resistance of interior layer test points. The surface preparation in any case shall not exceed that normally required when assembling a piping system using a fitting. The distance between the clamps should be six times the nominal diameter of the pipe, fitting, or joint when testing individual components and systems. If a specimen ends with an open flange, the grounding clamp will be installed on the face of the flange.

A3.7.3 Measure the lengths of the potential current paths of interest for test specimen including extenders (if used) and the thickness of any exposed flange faces.

A3.7.4 Isolate the test specimen from ground.

A3.7.5 Connect a $1 \times 10^6\ \Omega - 1$ W resistor in series with the test specimen.

A3.7.6 Apply a dc voltage of 1500 ± 0.1 V across the test specimen and resistor.

A3.7.7 Measure the voltage drop, V_1, across the test specimen. If immersion is not required, calculate the resistance in accordance with A3.7.14.

A3.7.8 If immersion is requested by the purchaser, place the specimens in the test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 60° to 80°F (15.5° to 26.7°C) throughout the duration of the test. Suggested test environments are: (1) Salt water per Specification D 1141, (2) Gasoline, (3) Bunker C, and (4) 1 % sulfuric acid.

A3.7.9 At the end of 1, 3, 6, and 12 months, remove the test specimens from the bath and rinse thoroughly with tap water if the test specimens have been exposed to a water soluble product or a hydrocarbon solvent if the specimens have been exposed to a petroleum product.

A3.7.10 Place the test specimens in an oven at 150° ± 10°F (66.6° ± 10°C) for a period of 2 h.

A3.7.11 At the end of 2 h, remove the specimens from the oven and allow them to cool to 70° to 80°F (21.1° to 26.7°C) in a 50 ± 5 % relative humidity environment for 60 ± 5 min before retesting.

A3.7.12 Remeasure the voltage drop across the specimens in accordance with A3.7.5 through A3.7.7.

A3.7.13 Note the appearance of the test specimens and the conditions of the clamps.

A3.7.14 Using the information obtained, calculate the resistance of the test specimen before and after exposure using the following equation:

$$\frac{V_1}{R_1} = \frac{V_2}{R_1 + R_2}$$

where:

V_1 = voltage drop across specimen,
R_1 = resistance of test specimen,
V_2 = line voltage (1500 V), and
R_2 = value of known resistor ($1 \times 10^6\ \Omega$).

A3.7.15 Calculate the resistance per unit length for each of the potential current paths of interest on the specimen and its associated resistance.

A3.8 Report

A3.8.1 Report the following information:

A3.8.1.1 Manufacturer of the specimen.

A3.8.1.2 Designation of product being tested.

A3.8.1.3 Description of the specimen including the diameter and length for a pipe, fitting, or joint (including the lengths of extensions, if applicable) or a dimensioned sketch for a representative piping system. In both cases, placement of the grounding clamps and the potential current paths and their lengths shall be identified.

A3.8.1.4 Description of grounding clamps and grounding procedure.

A3.8.1.5 Test media.

A3.8.1.6 Initial resistance per unit length between clamps for each potential current path and resistance per unit length for each potential current path at 1, 3, 6, and 12 months if immersion testing was conducted.

A3.8.1.7 Appearance of test specimen if immersion testing was conducted.

A3.8.1.8 Date of test.

A4. TEST METHOD FOR FIRE ENDURANCE EVALUATION OF PLASTIC PIPING IN THE DRY CONDITION

A4.1 Scope

A4.1.1 This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications when empty. This test procedure is based on the IMO Assembly Resolution A.753(18) which is an alternative to this test. SI units shall be used in referee decisions.

A4.2 Significance

A4.2.1 This testing procedure in this test method is applicable over a range of temperatures up to 2012°F (1100°C). This temperature rise occurs in less than 1 hour, simulating a fully developed liquid hydrocarbon fire. This test is valid for pipe 1 in. to 48 in. nominal diameters for pressures up to 225 psi.

A4.3 Test Equipment

A4.3.1 *Furnace*—Test furnace with the capability to increase its temperature to 2012°F (1100°C) within 1 h while meeting the accuracy in A4.6.4.1. Furnace shall have a temperature gauge capable of measuring temperature ±2 %.

A4.3.2 *Thermocouples*—Two thermocouples capable of measuring up to 2012°F (1100°C).

A4.3.3 Nitrogen tank with regulator.

A4.4 Test Specimen

A4.4.1 The test specimen should be prepared with the joints, fittings, and fire protection coverings intended for use in the proposed application.

A4.4.2 The number of specimens shall be sufficient to test typical joints and fittings including joints between non-metal and metal pipes and fittings to be used.

A4.4.3 The ends of the specimen shall be closed with one end allowing pressurized nitrogen to be connected.

A4.4.4 The pipe ends and closures may be outside the furnace.

A4.4.5 The general orientation of the specimen should be horizontal and it should be supported by one fixed support with the remaining supports allowing free movement.

A4.4.6 The free length between supports should not be less than 8 times the pipe diameter.

A4.4.7 Full scale fire test shall be performed on 1, 2, 4, and 8 inch pipe systems. Above 8-inch, every third size of the manufacturer's product line shall be tested.

TABLE A4.1 Time/Mean Temperature Ramp of Furnace

Time	Mean Temperature
at the end of: 5 minutes:	≥945°C
at the end of: 10 minutes:	≥1033°C
at the end of: 15 minutes:	≥1071°C
at the end of: 30 minutes:	≥1098°C
at the end of: 60 minutes:	≥1100°C

A4.5 Test Conditions

A4.5.1 *Fire-Protective Coatings:*

A4.5.1.1 If the fire protective coating contains, or is liable to absorb, moisture the specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 50 % relative humidity at 70 ± 10°F (20 ± 5°C).

A4.5.1.2 Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

A4.5.1.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

A4.5.2 A nitrogen pressure inside the test specimen should be maintained automatically at 0.7 ± 0.1 bar during the test. Means should be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen in order to indicate leakage.

A4.5.3 *Flame Temperature:*

A4.5.3.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (2.5 cm) from the pipe near the center span of the assembly.

A4.5.3.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

A4.5.3.3 The test temperature shall be taken as the average of the two thermocouple readings.

A4.6 Procedure

A4.6.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

A4.6.2 Place specimen in the furnace.

A4.6.3 Pressurize specimen with nitrogen maintaining the pressure in accordance with A4.5.2.

A4.6.4 Time/mean temperature ramp of furnace according to Table A4.1 is started.

A4.6.4.1 The accuracy of the furnace control should be as follows:

(*a*) During the first 10 min. of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±15 % of the area under the standard curve.

(*b*) During the first half hour of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±10 % of the area under the standard curve.

(*c*) For any ten minute period after the first half hour of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±5 % of the area under the standard curve.

(*d*) At any time after the first 10 min of the test the mean furnace temperature should not differ from the standard curve by more than ±100°C.

A4.6.5 The mean temperature and exterior flame temperature shall be recorded a minimum of once every 30 s.

A4.7 Acceptance Criteria

A4.7.1 No nitrogen leakage from the sample should occur during the test.

A4.7.2 *Hydrostatic Pressure:*

A4.7.2.1 After termination of the furnace test, the specimen together with fire protection coating, if any, should be allowed to cool in still air to ambient temperature and then test to the rated pressure of the pipe.

A4.7.2.2 The pressure should be held for a minimum of 15 min without leakage.

A4.7.2.3 Where practicable, the hydrostatic test should be conducted on bare pipe, that is pipe without any covering, including fire protection. This is to make any leakage readily apparent.

A4.8 Report

A4.8.1 Report the following information:

A4.8.1.1 Complete identification of the pipe or fitting tested including manufacturer's name and code.

A4.8.1.2 Description of fire-protective coating if applicable.

A4.8.1.3 Diameter of pipe, fitting or joint.

A4.8.1.4 Endurance time.

A4.8.1.5 Appearance of test specimen.

A4.8.1.6 Date of test.

A5. TEST METHOD FOR FIRE ENDURANCE TESTING OF WATER-FILLED PLASTIC PIPING

A5.1 Scope

A5.1.1 This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings and joints to be used in marine applications when in the wet condition. This test procedure is based on the IMO Assembly Resolution A.753(18) which is an alternative to this test. SI units shall be used in referee decisions.

A5.2 Summary of Test Method

A5.2.1 This test method subjects a pipe sample to a constant 36,011 Btu/(hr-ft·2) (113.6 kW/m·2) net flux to determine a pipe systems fire-endurance.

A5.3 Significance

A5.3.1 This test is valid for pipe 1 in. to 48 in. nominal diameters for pressures up to 225 psi. It will give a purchaser of fiberglass pipe the ability to determine the fire resistance of a fiberglass piping system when filled with water.

A5.4 Test Equipment

A5.4.1 *Sivert No. 2942 burner* or equivalent which produces an air mixed flame.

A5.4.1.1 The inner diameter of the burner heads should be 1.5 in. (29 mm) (see Fig. A5.1).

A5.4.1.2 The burner heads should be mounted in the same plane and supplied with gas from a manifold.

A5.4.1.3 If necessary, each burner should be equipped with a valve in order to adjust the flame height.

A5.4.1.4 The height of the burner stand should also be adjustable.

A5.4.1.5 It should be mounted centrally below the test pipe with the rows of burners parallel to the pipe's axis.

A5.4.1.6 The distance between the burner heads and the pipe should be maintained at 5 ± ⅜ in. (12.5 ± 1.0 cm) during the test.

A5.4.1.7 The free length of the pipe between its supports should be 31.5 ± 2 in. (0.80 ± 0.05 m).

A5.4.2 *Thermocouples*—Two thermocouples capable of

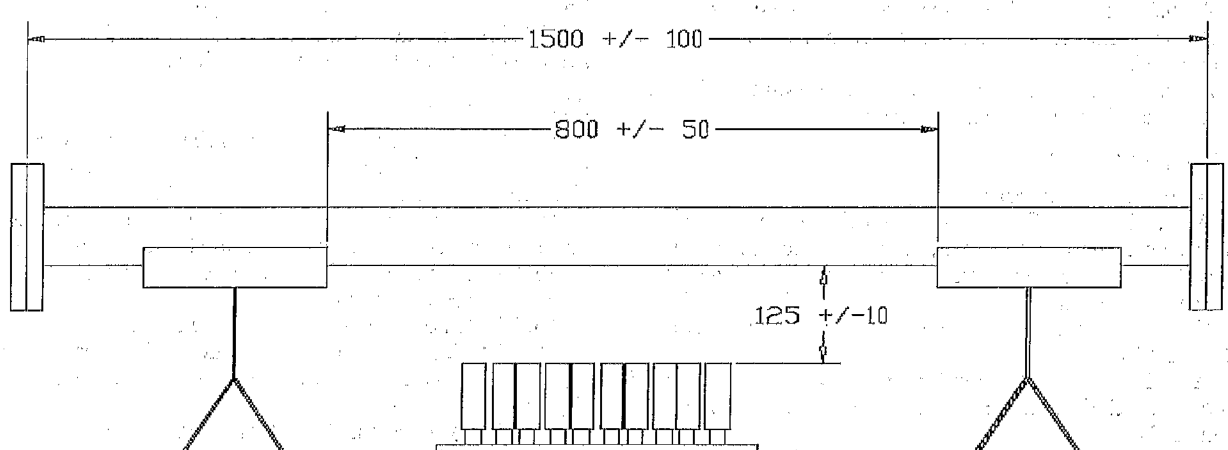


FIG. A5.1 Stand with Mounted Sample

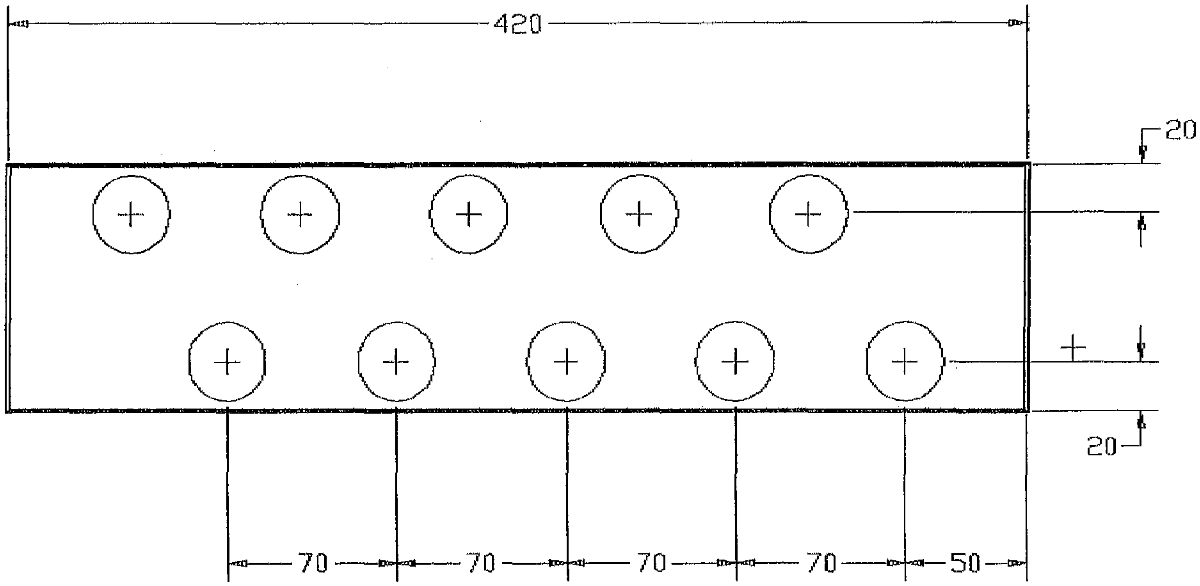


FIG. A5.2 Top View Burner Assembly

measuring up to 2012°F (1100°C).

A5.4.3 *Deaerated water.*

A5.4.4 *Thermometer*—To measure internal water temperature.

A5.4.5 *Pressure Gauge*—Capable of reading up to 5 bars (±5 %).

A5.4.6 *V-Shaped Pipe Supports.*

A5.5 Test Specimen

A5.5.1 *Specimen Length:*

A5.5.1.1 The test specimen should have a length of 59 in. (1.5 m).

A5.5.2 Test specimen should be pipe with permanent joints or fittings intended for use in marine applications.

A5.5.3 All joint types should be tested as they are the primary point of failure.

A5.5.4 The number of pipe specimens should be sufficient to test all typical joints and fittings.

A5.5.5 The ends of each specimen must be closed.

A5.5.6 One end should allow pressurized water to be connected.

A5.5.7 A pressure relief valve should be connected to one of the end closures of each specimen.

A5.6 Test Conditions

A5.6.1 *Fire-Protective Coatings:*

A5.6.1.1 If the fire-protective coating or covering contains, or is liable to absorb, moisture, the test specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 50 % relative humidity at 70 ± 10°F (20 ± 5°C).

A5.6.1.2 Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

A5.6.1.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

A5.6.2 The test should be carried out in a sheltered test site in order to prevent any draft influencing the test.

A5.6.3 Each pipe specimen should be completely filled with deaerated water and vented to exclude air bubbles.

A5.6.3.1 The water temperature should not be less than 59°F (15°C) at the start and should be measured continuously during the test.

A5.6.3.2 The water inside the sample should be stagnant and the pressure maintained at 3 ± 0.5 bar during the test.

A5.6.4 *Flame Temperature:*

A5.6.4.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (2.5 cm) from the pipe near the center span of the assembly.

A5.6.4.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

A5.6.4.3 The test temperature shall be taken as the average of the two thermocouple readings.

A5.7 Procedure

A5.7.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

A5.7.2 Place specimen on two V-shaped supports. The supports may consist of two stands as shown in Fig. A5.1.

A5.7.3 Pressurize specimen with water maintaining conditions in accordance with A6.3.

A5.7.4 *Burner Configuration for Constant Heat Flux:*

A5.7.4.1 For piping 6 ins. and less in diameter, the fire source should consist of two rows of 5 burners as shown in Fig. A5.2.

A5.7.4.2 A constant heat flux averaging 36,011 Btu/(hr-ft·2) (113.6 kW/m·2) (±10 %) should be maintained 5 ± ⅜ in. (12.5 ± 1.0 cm) above the centerline of the array.

(*a*) This flux corresponds to a pre-mix flame of propane with a fuel flow rate of 11.02 lb/hr (5 kg/hr) for a total heat release of 221,780 btu/hr (65 kW).

(*b*) The gas consumption should be measured with an accuracy of at least ±3 % in order to maintain a constant heat flux.

A5.7.4.3 For piping greater than 6 in. in diameter, one additional row of burners should be included for each 2 inch increase in pipe diameter.

(*a*) A constant heat flux averaging 36,011 Btu/(hr-ft·2) 113.6 kW/m·2 (±10 %) should still be maintained at the 5 ± ⅜ in. (12.5 ± 1.0 cm) height above the centerline of the burner array.

(*b*) The fuel flow should be increased as required to maintain the designated heat flux.

A5.7.5 Begin heat flux.

A5.7.6 Record test temperature, water temperature, water pressure at least once every 30 s.

A5.8 Acceptance Criteria

A5.8.1 No leakage from the sample(s) should occur except that slight weeping from the wall may be accepted.

A5.8.2 *Hydrostatic Pressure:*

A5.8.2.1 After termination of the burner regulation test, the test sample, together with the fire protection coating, if any, should be allowed to cool to ambient temperature and then tested to the rated pressure of the pipe.

A5.8.2.2 The pressure should be held for a minimum of 15 min and produce a leakage of less than 0.05 gpm (0.2 liters/min).

A5.8.2.3 Where practical, the hydrostatic test should be conducted on bare pipe that has had all of its coverings, including fire protection insulation removed, so that leakage will be readily apparent.

A5.9 Report

A5.9.1 Report the following information:

A5.9.1.1 Complete identification of the pipe, fitting or joint tested including manufacturer's name and code.

A5.9.1.2 Description of fire-protective coating if applicable.

A5.9.1.3 Diameter of pipe, fitting or joint.

A5.9.1.4 Endurance time.

A5.9.1.5 Appearance of test specimen.

A5.9.1.6 Date of test.

A6. DIMENSIONS AND TOLERANCES

A6.1 For Pipe

A6.1.1 *Diameter*—Pipe meeting this specification shall conform to the requirements in Table A6.1 or Table A6.2. Dimensions shall be determined in accordance with 11.4.

A6.1.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not, at any point, be less than:

A6.1.2.1 Eighty-five percent of the nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 11.4.

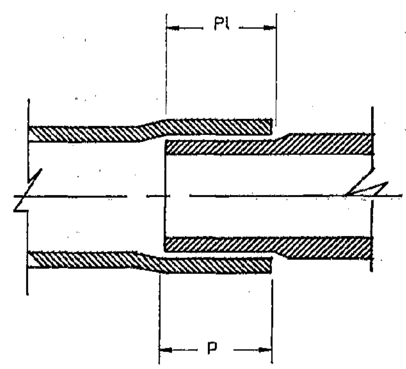
A6.1.2.2 The wall thickness determined using hydrostatic design basis in accordance with 7.2.

A6.1.3 *Liner thickness*—Except for unlined products, all pipe shall have a minimum liner thickness of 0.010 in. (0.254 mm) when measured in accordance with 11.4.

A6.1.4 *Length*—Pipe shall be in lengths as specified by

TABLE A6.1 Dimensions for Outside Diameter (OD) Series Pipe

Steel NPS	Outside Diameter	
	in., min	mm, min
1	1.31	33.4
1½	1.90	48.3
2	2.37	60.3
3	3.50	88.9
4	4.50	114.3
6	6.625	168.3
8	8.625	219.1
10	10.75	273.1
12	12.75	323.9
14	14.00	355.6
16	16.00	406.4
18	18.04	458.1
20	20.04	509.0
22	22.04	559.8
24	24.05	610.9
26	26.04	661.5
28	28.04	712.2
30	30.04	762.9
32	32.04	813.8
34	34.04	864.7
36	36.04	915.5



NPS	Minimum Socket Length, P in. (mm)	Minimum Spigot Length, P1 in. (mm)	Spigot Diameter	
			Minimum in. (mm)	Maximum in. (mm)
1	1.063 (27)	1.125 (29)	1.277 (32.4)	1.293 (32.8)
1½	1.250 (32)	1.125 (35)	1.876 (47.4)	1.883 (47.8)
2	1.813 (46)	2.000 (51)	2.330 (59.2)	2.346 (59.6)
3	1.813 (46)	2.000 (51)	3.450 (87.6)	3.466 (88.0)
4	1.813 (46)	2.000 (51)	4.430 (112.5)	4.446 (112.9)
6	2.250 (57)	2.375 (60)	6.544 (166.2)	6.560 (166.6)
8	2.500 (64)	2.625 (67)	8.544 (217.0)	8.560 (217.4)
10	2.750 (70)	2.875 (73)	10.680 (271.3)	10.696 (271.7)
12	3.000 (76)	3.125 (79)	12.684 (322.2)	12.700 (322.6)
14	3.500 (88)	3.625 (92)	13.945 (354.2)	13.970 (354.8)
16	4.000 (102)	4.125 (105)	15.909 (404.1)	15.925 (404.5)

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.1 Standard Straight-Taper and Straight-to-Straight Joints

TABLE A6.2 Dimensions for Inside Diameter (ID) Series Pipe

Steel NPS	Inside Diameter	
	in.	mm
1	1.00 ± 0.06	25.4 ± 1.52
1½	1.50 ± 0.06	38.1 ± 1.52
2	2.00 ± 0.06	50.8 ± 1.52
3	3.00 ± 0.12	76.2 ± 3.05
4	4.00 ± 0.12	101.6 ± 3.05
6	6.00 ± 0.25	152.4 ± 6.35
8	8.00 ± 0.25	203.2 ± 6.35
10	10.00 ± 0.25	254.0 ± 6.35
12	12.00 ± 0.25	304.8 ± 6.35
14	14.00 ± 0.25	355.6 ± 6.35
16	16.00 ± 0.25	406.4 ± 6.35
18	18.00 ± 0.25	457.2 ± 6.35
20	20.00 ± 0.25	508.0 ± 6.35
22	22.00 ± 0.25	558.8 ± 6.35
24	24.00 ± 0.25	609.6 ± 6.35
26	26.00 ± 0.25	660.4 ± 6.35
28	28.00 ± 0.25	711.2 ± 6.35
30	30.00 ± 0.25	762.0 ± 6.35
32	32.00 ± 0.25	812.8 ± 6.35
34	34.00 ± 0.25	863.6 ± 6.35
36	36.00 ± 0.25	914.4 ± 6.35

the purchase order when measured in accordance with 11.4.

A6.2 For Fittings

A6.2.1 *Wall thickness*—The minimum wall thickness of fittings furnished under this specification shall not, at any point, be less than the pipe nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 11.4.

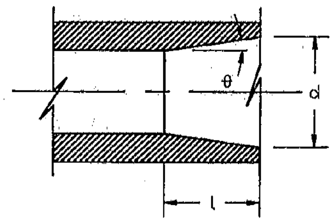
A6.2.2 Except for unlined products, the fittings shall have a minimum liner of 0.010 inches (0.254 mm) when measured in accordance with 11.4.

A6.2.3 *Length*—Lengths and tolerances are specified in Figs. A6.1 through A6.16.

NOTE 1—Outside diameters other than those listed in Table A6.1 or inside diameters as listed in Table A6.2 shall be permitted upon agreement between the manufacturer and the purchaser.

NOTE 2—Outside diameters approximate those for iron pipe size, ISO International Standard 559-1978, and for cast iron pipes, ISO International Standard 13-1978, as follows:

NOTE 3—Tolerances for 1 to 16 NPS in accordance with Specification D 2996 Figures. Tolerances for 18 to 36 NPS are ±1 % of the pipe outside diameter in accordance with ISO 559-1978.



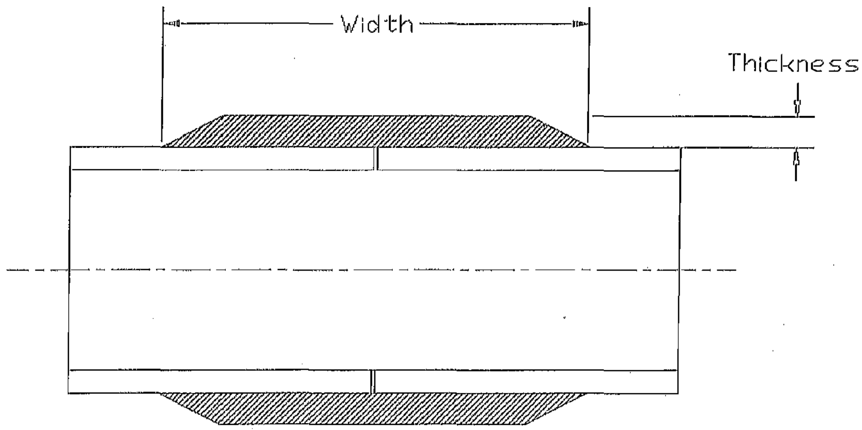
NPS	Socket Entrance Diameter, min, d, in. (mm)	Minimum Effective Bond Length, min, L, in. (mm)	Taper Angle Range ° (Degrees)
1	1.335 (34)	0.750 (19)	1 to 3
1½	1.910 (76)	0.750 (19)	1 to 3
2	2.375 (60)	1.000 (25)	1 to 2
3	3.500 (89)	1.125 (29)	1 to 2
4	4.500 (114)	1.250 (32)	1 to 2
6	6.600 (168)	1.500 (38)	1 to 2
8	8.635 (219)	2.000 (51)	1 to 2
10	10.700 (272)	2.125 (54)	1 to 2
12	12.670 (322)	2.250 (57)	1 to 2
14	14.400 (366)	2.500 (64)	1 to 2
16	16.460 (418)	2.500 (64)	1 to 2

NOTE 1—*Standard tapered socket*. In all cases, the base angle for bells (sockets) shall be the same as the angle for the pipe spigots (male tapers). The tolerances shall be set to ensure there is no gap between the end of the spigot and the bottom of the bell. The minor I.D. (diameter at the bottom) of the tapered socket shall always be less than the end dimension (the diameter at the end) of the pipe spigot to ensure that the spigot does not insert beyond the tapered portion of the bell. The insertion of the spigot into the bell shall be at least equal to the minimum allowable effective bond length (EBL) shown for Fig. A6.2. The minimum effective bond length is the minimum insertion length where the tapered spigot surfaces are in contact with the tapered bell surfaces. The tolerances shall be set to ensure that the effective bond length is at least equal to the values in Fig. A6.2. Angle tolerance for male tapers (spigots) and for female tapers (bells) shall not vary more than 0.25° i.e. the most extreme mismatch in a bonded joint must never exceed 0.5°. For all bonded joints, the angle for the spigot shall be equal to or less than the bell angle (preventing a gap between the end of the spigot and the bottom of the bell).

NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

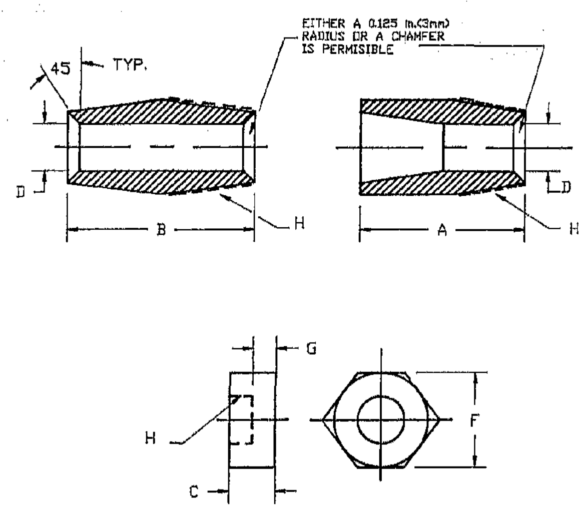
FIG. A6.2 Standard Taper-to-Taper Joint

A6.2.4 The lengths and tolerances of fittings not covered in Annex A6 must be agreed upon by the purchaser and the supplier.



NPS	Width, min, in.	Thickness, min, in.
2	3	0.125
3	3	0.125
4	3	0.125
6	4	0.175
8	4	0.175
10	6	0.2
12	6	0.25
14	8	0.25
16	19	0.25

FIG. A6.3 Standard Butt-And-Wrap

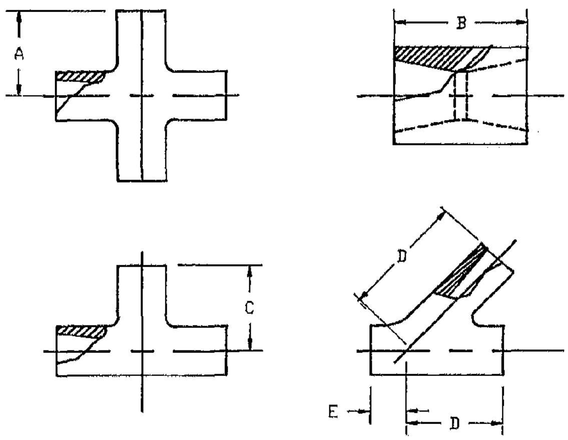


NPS	Overall Length, min			Minimum Internal Diameter D, in. (mm)	Width[A] Across Hex Flats F, in. (mm)	Minimum Thickness G, in. (mm)	Pipe Thread (IPS) H, in. (mm)	Taper[B] Angle Degrees °
	A, in. (mm)	B, in. (mm)	C, in. (mm)					
1	3.250 (83)	2.375 (60)	1.500 (38)	0.875 (22)	1.688 (43)	0.438 (11)	NPT	1 to 3
1½	3.250 (83)	2.500 (64)	1.750 (44)	1.500 (38)	2.438 (62)	0.500 (13)	NPT	1 to 3
2	4.000 (102)	3.500 (89)	2.000 (51)	1.890 (48)	3.000 (76)	0.563 (14)	NPT	1 to 2

[A] Width across hex flats tolerance +0.000 and −0.063 in. [+0.000 and −0.005 mm].

NOTE 1—Machining of threads shall be accordance with ANSI B2.1 for NPT threads.
NOTE 2—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

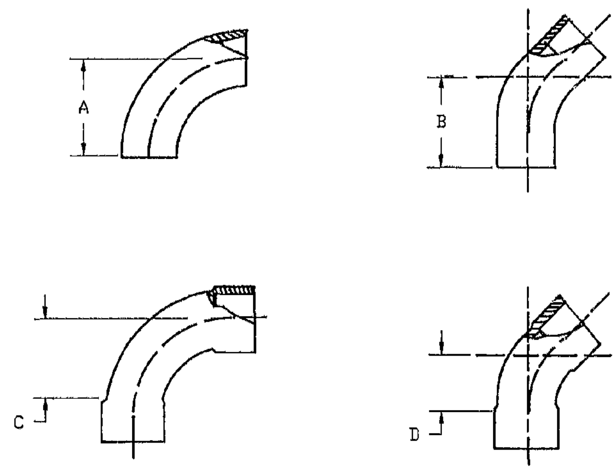
FIG. A6.4 (A) Standard Adapter, Tapered Spigot × Male Pipe Thread; (B) Standard Adapter Tapered × Male Pipe Thread; and (C) Hexagonal Threaded Cap



NPS	A, min, in. (mm)	B, min, in. (mm)	C, min, in. (mm)	D, min, in. (mm)	E, min, in. (mm)
1	2.500 (64)	2.500 (64)	2.500 (64)	3.625 (92)	2.250 (57)
1½	3.125 (79)	3.000 (76)	3.125 (79)	5.000 (127)	3.000 (76)
2	3.125 (79)	4.625 (117)	3.125 (79)	6.375 (162)	2.500 (64)
3	4.375 (111)	4.750 (121)	4.375 (111)	7.500 (191)	4.000 (102)
4	4.875 (124)	5.000 (127)	4.875 (124)	8.750 (222)	4.125 (105)
6	5.875 (149)	6.750 (171)	5.875 (149)	12.250 (311)	5.500 (140)
8	11.375 (289)	9.750 (248)	11.375 (289)	16.000 (406)	7.125 (181)
10	12.875 (327)	10.250 (260)	12.875 (327)	19.375 (492)	8.500 (216)
12	13.750 (349)	10.750 (273)	13.750 (349)	24.500 (622)	11.500 (292)
14	15.750 (400)	12.250 (311)	15.750 (400)	32.250 (819)	15.500 (394)
16	16.750 (425)	12.750 (324)	16.750 (425)	35.500 (902)	17.500 (445)

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.
NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.5 Taper-to-taper (A) Cross, (B) Coupling, (C) Tee, and (D) 45° Lateral

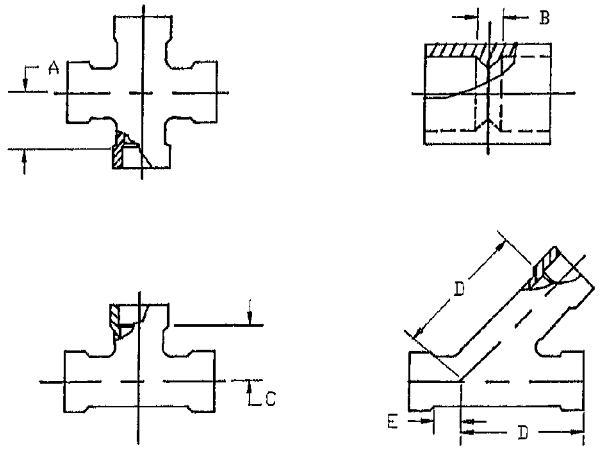


NPS	A, min, in. (mm)A	B, min, in. (mm)A	C, min, in. (mm)	D, min, in. (mm)
1	2.500 (64)	2.125 (54)	2.562 (65)	0.875 (22)
1½	3.125 (79)	2.625 (67)	3.188 (81)	0.125 (29)
2	3.125 (79)	2.375 (60)	3.000 (76)	1.375 (35)
3	4.375 (111)	3.505 (89)	4.500 (114)	2.000 (51)
4	4.875 (124)	3.625 (92)	6.000 (152)	2.500 (64)
6	5.875 (149)	4.125 (105)	9.000 (229)	3.750 (95)
8	11.375 (289)	7.875 (200)	12.000 (305)	5.000 (127)
10	12.875 (327)	8.375 (213)	15.000 (381)	6.250 (155)
12	13.750 (349)	9.250 (235)	18.000 (457)	7.500 (151)
14	15.750 (400)	10.000 (254)	14.125 (359)	4.750 (120)
16	17.000 (432)	10.625 (270)	15.125 (397)	5.375 (136)

A For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

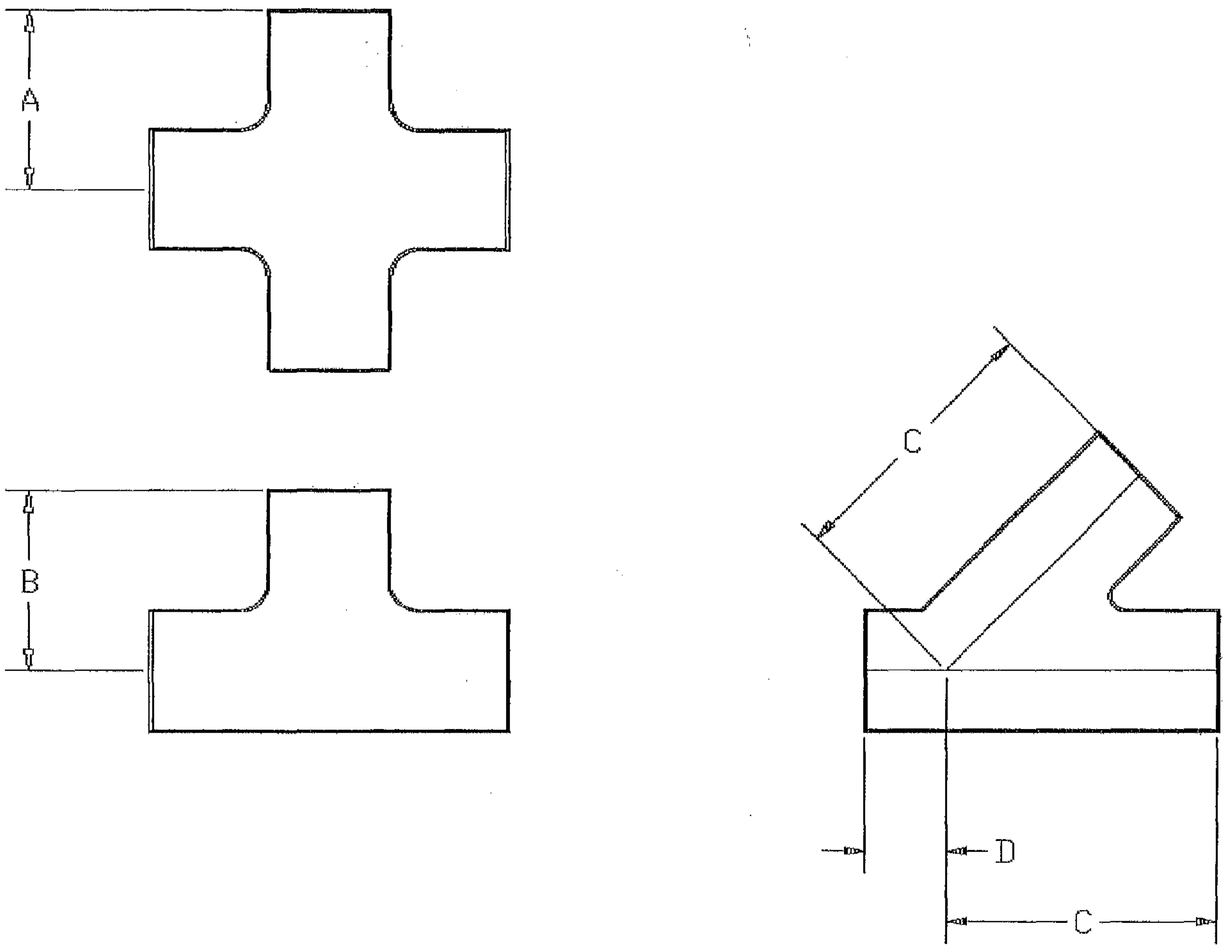
FIG. A6.6 Taper-to-Taper and Butt-Weld: (A) 90° Elbows and (B) 45° elbows; Straight-Taper and Straight-to-Straight (C) 90° Elbows and (D) 45° elbows



NPS	A, min, in. (mm)	B, min, in. (mm)	C, min, in. (mm)	D, min, in. (mm)	E, min, in. (mm)
1	1.063 (27)	0.375 (10)	0.063 (27)	3.000 (76)	1.000 (25)
1½	1.188 (30)	0.375 (10)	1.188 (30)	4.000 (102)	1.500 (38)
2	2.500 (64)	0.375 (10)	2.500 (64)	8.000 (203)	2.500 (64)
3	3.375 (86)	0.375 (10)	3.375 (86)	10.000 (254)	3.000 (76)
4	4.125 (105)	0.375 (10)	4.125 (105)	12.000 (305)	3.000 (76)
6	5.125 (143)	0.375 (10)	5.625 (143)	14.500 (368)	3.500 (89)
8	7.000 (178)	0.375 (10)	7.000 (178)	17.500 (445)	4.500 (114)
10	8.500 (216)	0.375 (10)	8.500 (216)	20.500 (521)	5.000 (127)
12	10.000 (254)	0.375 (10)	10.000 (254)	24.500 (622)	5.500 (140)
14	10.500 (267)	0.750 (19)	10.500 (267)	24.500 (622)	5.500 (140)
16	11.500 (292)	0.750 (19)	11.500 (292)	24.500 (622)	5.500 (140)

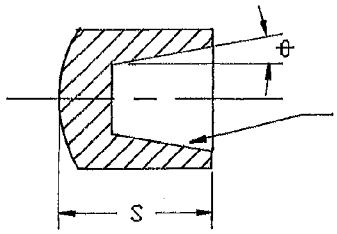
NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.7 Straight-Taper and Straight-to-Straight (A) Cross, (B) Coupling, (C) Tee, and (D) & (E) 45° Lateral



NPS	A, min, in.	B, min, in.	C, min, in.	D, min, in.
2	5	5	9	5
3	6	6	11	5
4	7	7	13	5
6	9	9	15	7
8	11	11	19	9
10	13	13	23	09
12	15	15	25	11
14	17	17	29	11
16	19	19	31	13

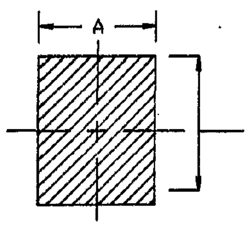
FIG. A6.8 Plain End (A) Cross, (B) Tee, and (C) & (D) 45° Lateral



NPS	Cap Length, S, min, in. (mm)
1	2.250 (57)
1½	2.375 (60)
2	2.500 (64)
3	3.000 (76)
4	3.500 (89)
6	4.625 (117)
8	6.500 (165)
10	7.000 (178)
12	8.750 (222)
14	10.500 (267)
16	11.500 (292)

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

FIG. A6.9 End Cap: Taper-to-Taper



NPS	Plug Length, A, in. (mm)
1	1.188 (30)
1½	1.375 (35)
2	1.937 (49)
3	1.937 (49)
4	1.937 (49)
6	2.375 (60)
8	2.625 (67)
10	2.875 (73)
12	3.125 (79)
14	3.625 (92)
16	4.125 (105)

NOTE 1—For straight taper socket dimensions, see Fig. 1.

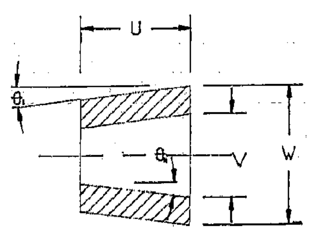
FIG. A6.10 Pipe Cap Fitting Plug: Straight-Taper

NPS	A, min, in. (mm)	B, min, in. (mm)[A]
1½ by 1	*A = 2.5* (Outside Diameter − Inside Diameter)*	1.250 (32)
2 by 1		2.500 (64)
2 by 1½		1.250 (32)
3 by 1½		3.000 (76)
3 by 2		2.120 (54)
4 by 2		3.000 (76)
4 by 3		2.880 (73)
6 by 3		3.810 (94)
6 by 4		3.690 (94)
8 by 4		5.440 (138)
8 by 6		3.880 (98)
10 by 6		4.620 (117)
10 by 8		4.120 (105)
12 by 8		5.880 (149)
12 by 10		5.380 (137)
14 by 10		16.620 (422)
14 by 12		16.620 (422)
16 by 12		18.620 (473)
16 by 14		18.880 (479)

[A] For straight taper joint, only.

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.
NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

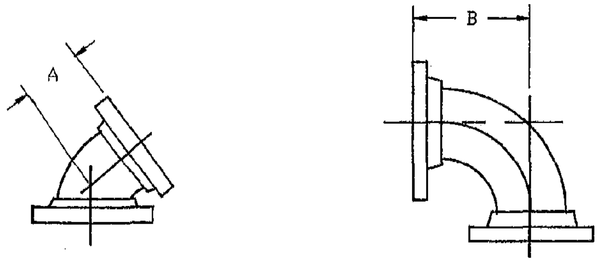
FIG. A6.11 Taper Body Reducer: (A) Taper by Taper and Plain end; (B) Straight-Taper and Straight by Straight



NPS	Bushing Length, min, U, in. (mm)
1½ by 1	1.125 (29)
2 by 1	1.375 (35)
2 by 1½	1.375 (35)
3 by 2	1.880 (41)
4 by 3	1.960 (67)
6 by 4	2.250 (57)
8 by 6	2.750 (70)
10 by 8	3.750 (95)
12 by 10	4.250 (108)
14 by 12	5.250 (133)
16 by 14	5.750 (146)

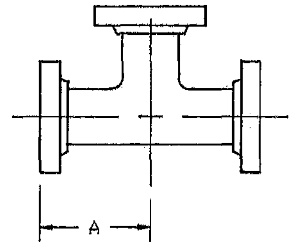
NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2. For external taper, see note 1, Fig. A6.2 (reference spigot design).

FIG. A6.12 Concentric Reducer Bushing: Taper-to-Taper



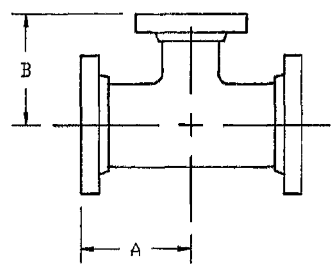
NPS	A, min, in. (mm)	B, min, in. (mm)
18	17.250 (438)	27.000 (432)
20	19.000 (483)	30.000 (762)
22	20.875 (530)	33.750 (857)
24	22.750 (578)	36.000 (914)
26	24.500 (622)	39.750 (1010)
28	26.375 (670)	42.750 (1086)
30	26.500 (673)	45.000 (1143)
32	30.000 (762)	48.750 (1238)
34	31.875 (810)	51.750 (1314)
36	29.000 (737)	54.000 (1372)

FIG. A6.13 (A) 45 Degree Flanged Elbow (B) 90 Degree Flanged Elbow



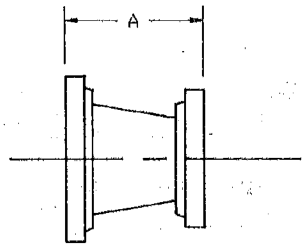
NPS	Center to Contact Surface "A", min, in. (mm)
18	22.500 (572)
20	24.750 (629)
22	27.000 (686)
24	29.250 (743)
26	31.500 (800)
28	33.750 (857)
30	35.500 (902)
32	38.250 (972)
34	40.500 (1029)
36	40.500 (1029)

FIG. A6.14 Tee Flanged



NPS	Center to Contact Surface		NPS	Center to Contact Surface	
	Main, A, min, in. (mm)	Branch, B, min, in. (mm)		Main A, min, in. (mm)	Branch, B, min, in. (mm)
18 by 18 by 8	22.500 (572)	17.026 (389)	28 by 28 by 22	33.750 (857)	30.000 (762)
10	22.500 (572)	18.026 (465)	24	33.750 (857)	31.250 (794)
12	22.500 (572)	18.067 (478)	26	33.750 (857)	32.500 (826)
14	22.500 (572)	20.005 (510)	30 by 30 by 18	35.500 (902)	28.500 (724)
16	22.500 (572)	21.005 (535)	20	35.500 (902)	29.750 (756)
20 by 20 by 10	24.750 (629)	19.026 (491)	22	36.000 (914)	31.000 (787)
12	24.750 (629)	19.067 (503)	24	35.500 (902)	32.250 (819)
14	24.750 (629)	21.005 (510)	26	36.000 (914)	33.500 (851)
16	24.750 (629)	22.005 (560)	28	36.000 (914)	34.750 (883)
18	24.750 (629)	23.500 (597)	32 by 32 by 20	38.250 (972)	30.750 (781)
24 by 24 by 12	29.250 (743)	22.026 (567)	22	38.250 (972)	32.000 (813)
14	29.250 (743)	23.005 (586)	24	38.250 (972)	33.250 (845)
16	29.250 (743)	24.005 (611)	26	38.250 (972)	34.500 (876)
18	29.250 (743)	25.500 (648)	28	38.250 (972)	35.750 (908)
20	29.250 (743)	25.500 (648)	34 by 34 by 22	40.500 (1029)	33.000 (838)
22	29.250 (743)	26.750 (679)	24	40.500 (1029)	34.250 (870)
26 by 26 by 14	31.500 (800)	24.000 (610)	26	40.500 (1029)	35.500 (902)
16	31.500 (800)	25.000 (635)	28	40.500 (1029)	36.750 (933)
18	31.500 (800)	26.500 (673)	30	40.500 (1029)	38.000 (965)
20	31.500 (800)	27.750 (705)	32	40.500 (1029)	39.250 (997)
22	31.500 (800)	29.000 (737)	36 by 36 by 24	40.500 (1029)	35.250 (895)
24	31.500 (800)	30.250 (768)	26	42.750 (1086)	36.500 (927)
28 by 28 by 16	33.750 (857)	26.000 (660)	28	42.750 (1086)	37.750 (959)
18	33.750 (857)	27.500 (699)	30	40.500 (1029)	39.000 (991)
20	33.750 (857)	28.750 (730)	32	42.750 (1086)	40.250 (1022)

FIG. A6.15 Reducer Tee Flanged



NPS	Center to Contact Surface "A", min, in. (mm)
18 by 14	19.000 (483)
16	19.000 (483)
20 by 16	20.000 (508)
18	20.000 (508)
22 by 18	22.000 (559)
20	22.000 (559)
24 by 20	24.000 (610)
22	24.000 (610)
26 by 22	26.000 (660)
24	26.000 (660)
28 by 24	28.000 (711)
26	28.000 (711)
30 by 26	30.000 (762)
28	30.000 (762)
32 by 28	32.000 (813)
30	32.000 (813)
34 by 30	34.000 (864)
32	34.000 (864)
36 by 30	35.000 (889)
32	36.000 (914)

FIG. A6.16 Reducer Flanged

The American Society for Testing and Materials 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.

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 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, 1916 Race St., Philadelphia, PA 19103.

CERTIFICATE

By Authority Of
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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

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WASHINGTON, D.C.

Designation: F 1199 – 88 (Reapproved 1998)

An American National Standard

Standard Specification for Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150°F Maximum)[1]

This standard is issued under the fixed designation F 1199; 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 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)[2]

2.2 *ANSI Standards:*[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:*[4]

SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings

SP-63 High Strength Wrought Welding Fittings

2.4 *ASME Standard:*[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.

4.1.2 *Duplex* (or Multiplex)—A strainer usually consisting

[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.

Current edition approved Dec. 30, 1988. Published February 1989.

[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

[5] Available from Manufacturers Standardization Society of the Valve and Fitting Industry, Inc., 1815 N. Fort Myer Dr., Arlington, VA 22209.

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:

¾ in. (19 mm) NPS and below . . . 1500 psig (10.3 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

7.3 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.

7.4 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 the 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 (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 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 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

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM F1200: Standard Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150°F)

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1200 – 88 (Reapproved 1998) An American National Standard

Standard Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150°F)[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[2]

F 722 Specification for Welded Joints for Shipboard Piping Systems[3]

F 1199 Specification for Cast (all Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150°F Maximum)[3]

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 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:*[5]

SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings

SP-63 High Strength Wrought Welding Fittings

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 *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.

4. Classification

4.1 Strainers may be classified into three general construction categories, simplex, duplex (or multiplex), and automatic

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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.

Current edition approved Dec. 30, 1988. Published February 1989.

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 01.07.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] Available from Manufacturers Standardization Society of the Valve and Fitting Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.

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

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1201 – 88 (Reapproved 1998)

An American National Standard

Standard Specification for Fluid Conditioner Fittings in Piping Applications Above 0°F[1]

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 Tester[2]

F 722 Specification for Welded Joints for Shipboard Piping Systems[3]

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.

4. Classification

4.1 *Class I*—Fluid conditioner fitting meeting the following requirements:

[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.

Current edition approved December 30, 1988. Published February 1989.

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 01.07.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th 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, 345 E. 47th St., New York, NY 10017.

Service	Pressure, psig (MPa)	Temperature, °F (°C)
Liquefied flammable gas	above 150 (1.03) . . . and . . .	above 0 (−18)
Fuels	above 150 (1.03) . . . or . . .	above 150 (66)
Liquids with a flash point[A] 150°F (66°C) or below	above 225 (1.55) . . . or . . .	above 150 (66)
Liquids with a flash point above 150°F (66°C)[B]	above 225 (1.55) . . . or . . .	above 400 (204)
Steam, gases, and vapors	above 150 (1.03) . . . or . . .	above 650 (343)
Water	above 225 (1.55) . . . or . . .	above 350 (177)

[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-ft^3 (0.042-m^3) 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-ft^3 (0.042-m^3) 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 ¾ 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 1½ 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 2½ (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,* 1½ in. (38 mm).

7.2.1.2 *Width,* twice the width of the fluid conditioner fitting but no less than 8½ 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 2½-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 2½-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

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM F1273: Standard Specification for Tank Vent Flame Arresters

CFR Section(s): 46 CFR 32.20-10

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1273 – 91 (Reapproved 1996)[ε1]

An American National Standard

Standard Specification for Tank Vent Flame Arresters[1]

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.

[ε1] NOTE—Keywords were added editorially in November 1996.

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[2]

F 1155 Practice for Selection and Application of Piping System Materials[2]

2.2 *ANSI Standard:*

B16.5 Pipe Flanges and Flanged Fittings[3]

2.3 *Other Documents:*

ASME Boiler and Pressure Vessel Code:

Section VIII, Division 1, Pressure Vessels;

Section IX, Welding and Brazing Qualifications[4]

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 Tankers[5]

International Electrotechnical Commission:

Publication 79-1–Electrical Apparatus for Explosive Gas Atmospheres[6]

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 non-leaded 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

[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.

Current edition approved April 1, 1991. Published June 1991.

[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[5] Available from International Maritime Organization, 4 Albert Embankment, London SE1 7SR, England.

[6] Available from International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland.

TABLE 1 Gases and Their MESGs

Inflammable Gas or Vapor	Maximum Experimental Safe Gap	
	mm	in.
Methane	1.170	0.046
Blast furnace gas	1.193	0.047
Propane	0.965	0.038
Butane	1.066	0.042
Pentane	1.016	0.040
Hexane	0.965	0.038
Heptane	0.965	0.038
Iso-octane	1.040	0.041
Decane	1.016	0.040
Benzene	0.99	0.039
Xylene	1.066	0.042
Cyclohexane	0.94	0.037
Acetone	1.016	0.040
Ethylene	0.71	0.028
Methyl-ethyl-ketone	1.016	0.040
Carbon monoxide	0.915	0.036
Methyl-acetate	0.990	0.039
Ethyl-acetate	1.04	0.041
Propyl-acetate	1.04	0.041
Butyl-acetate	1.016	0.040
Amyl-acetate	0.99	0.039
Methyl alcohol	0.915	0.036
Ethyl alcohol	1.016	0.040
Iso-butyl-alcohol	0.965	0.038
Butyl-alcohol (Normal)	0.94	0.037
Amyl-alcohol	0.99	0.039
Ethyl-ether	0.864	0.034
Coal gas (H_2 57 %)	0.482	0.019
Acetylene	<0.025	<0.001
Carbon disulphide	0.203	0.008
Hydrogen	0.102	0.004
Blue water gas (H_2 53 % CO 47 %)	0.203	0.008
Ethyl nitrate	<0.025	<0.001
Ammonia	3.33	0.133
Ethylene oxide	~0.65	~0.026
Ethyl nitrite	0.922	0.036

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 F 1155, 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 gas tight 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 B16 standards in Practice F 1155. Welded joints shall comply with Specification F 722.

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 F 722. 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 ½ in. nominal pipe size (NPS ½).

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, etc., 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, etc., 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:*

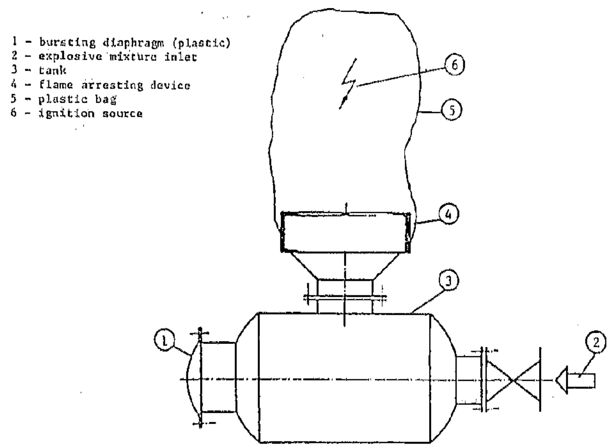

FIG. 1 Test Rig for Flash Back Test

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,[8] 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.

9.3 *Endurance Burn Test:*

[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] In order 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.

9.3.1 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 ASTM designation 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 designation number 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

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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WASHINGTON, D.C.

Designation: F 1321 – 92

An American National Standard

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[1]

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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 in order 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 in order 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 problems, 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 sea water density; the light 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 isn't 100 % complete, the weather isn't perfect, there ends up being water or shipyard trash in a tank that was supposed to

[1] This guide is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.01 on Structures.

Current edition approved Dec. 15, 1992. Published February 1993. Originally published as F 1321 – 90. Last previous edition F 1321 – 91.

be clean and dry, etc., 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 which 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 location of *M*, on the other hand, is essentially fixed over a range of heeling angles up to about 4°, as the ship is inclined at constant displacement and trim. The height of *M* above *K*, known as *KM*, is often plotted versus draft as one of the vessel's curves of form. If the difference from the design trim of the vessel is less than 1 % of its length, the *KM* can be taken directly from either the vessel's curves of form or hydrostatic tables. Because *KM* varies with trim, the *KM* must be computed using the trim of the ship at the time of the stability test when the difference from the design trim of the vessel is greater than 1 % of its length. Caution should be exercised 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.

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, $GZ = GM \sin \theta$. *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 $(W)(x)/\text{displ}$ 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 $GM \tan \theta$ and then equated to $(W)(x)/\text{displ}$. Rearranging this equation slightly results in the following equation:

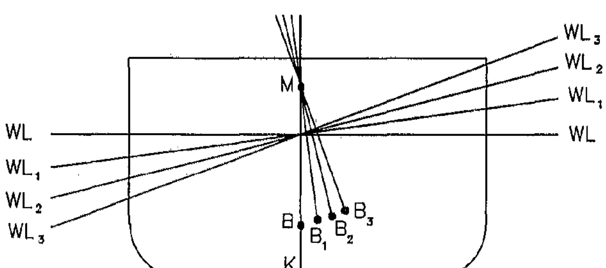

FIG. 1 Movement of the Center of Buoyancy

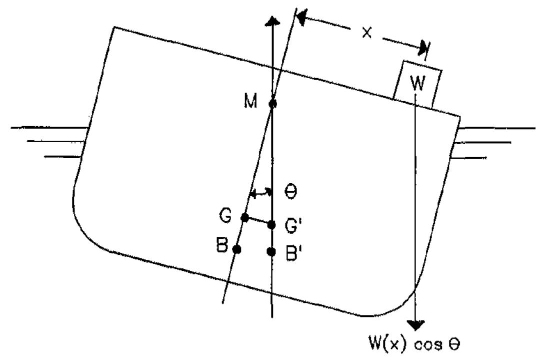

FIG. 2 Metacentric Height

$$GM = \frac{(W)(x)}{(\text{displ})(\tan \theta)} \quad (1)$$

Since *GM* and displ remain constant throughout the inclining experiment the ratio $(W)(x)/\tan \theta$ 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 experi-

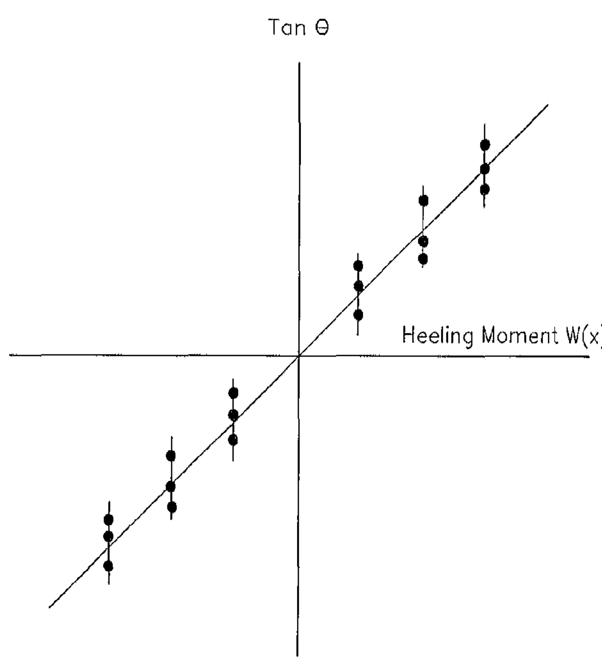

FIG. 3 A Typical Incline Plot

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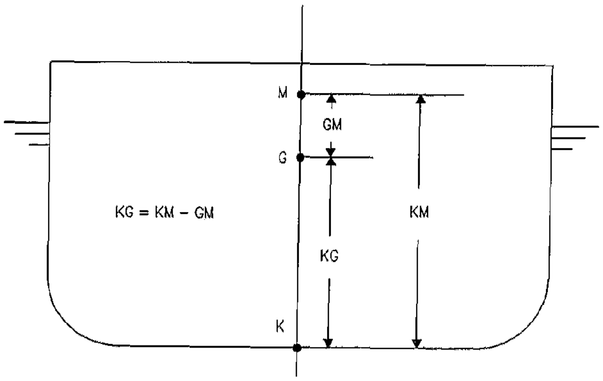


FIG. 4 Relationship between GM, KM, and KG

ment. 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. In order to accurately measure this angle (θ), 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 θ is then calculated:

$$\tan \theta = Z/Y \quad (2)$$

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. Figures 6 through 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

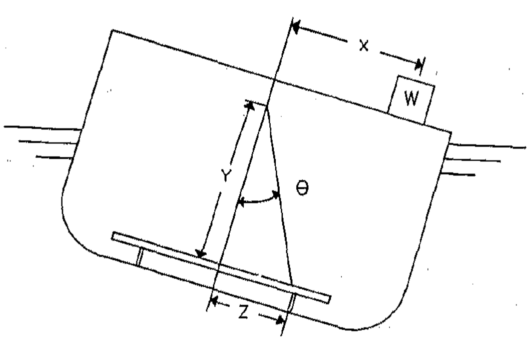
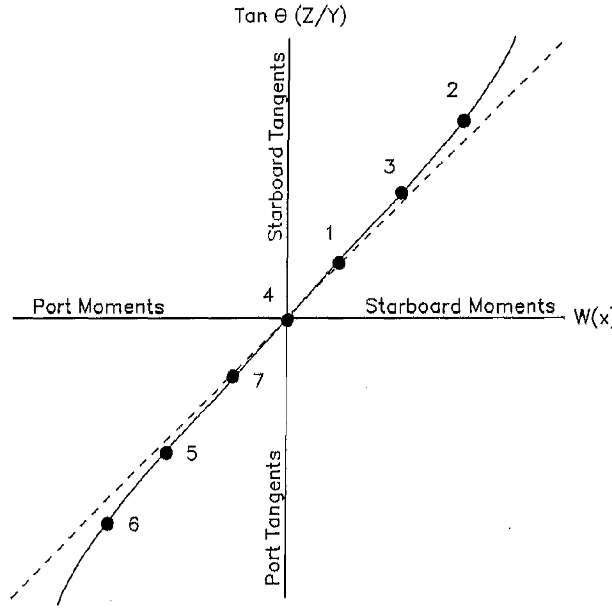


FIG. 5 Measuring the Angle of Inclination

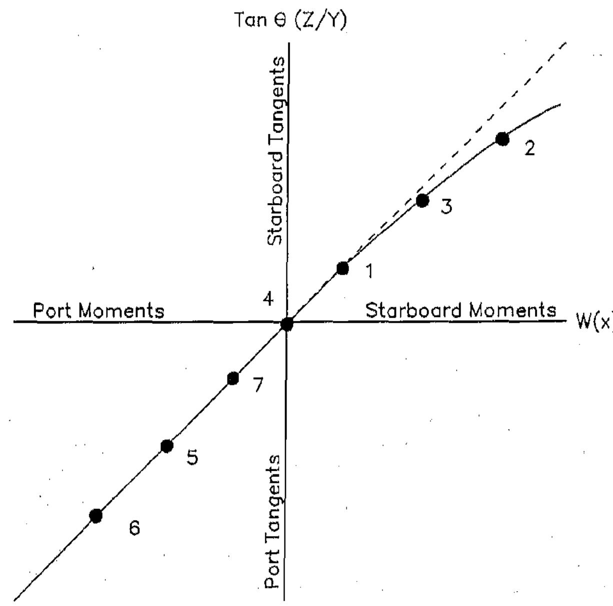


NOTE—Re-check all tanks and voids and pump out as necessary; Re-do all weight movements and re-check freeboard and draft readings

FIG. 6 Excessive Free Liquids

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



NOTE—Take water soundings and check lines; re-do weight movements 2 and 3.

FIG. 7 Vessel Touching Bottom or Restrained by Mooring Lines

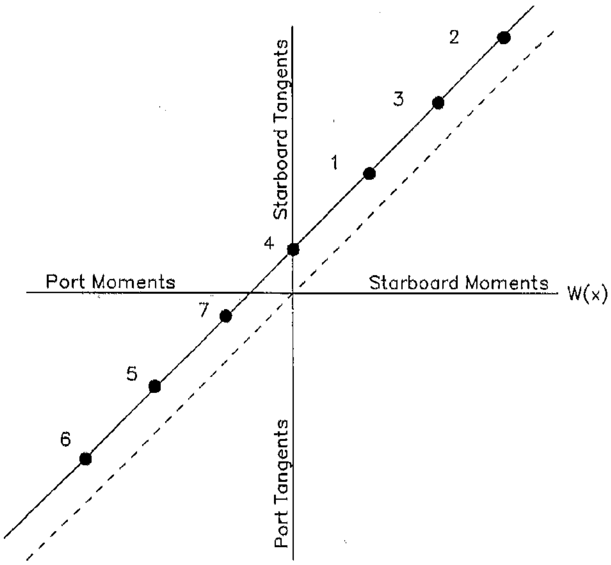
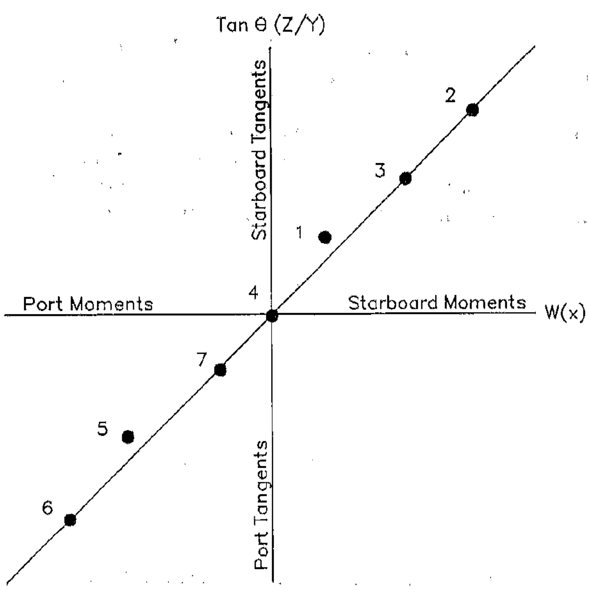


FIG. 8 Steady Wind From Port Side Came Up After Initial Zero Point Taken (Plot Acceptable)



NOTE—Re-do weight movements 1 and 5.

FIG. 9 Gusty Wind From Port Side

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 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 in order 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, etc.) 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:

$$\text{Free surface (ft-tons)} = lb^3/12Q \tag{3}$$

where:

l = length of tank, ft,
b = breadth of tank, ft, and
Q = specific volume of liquid in tank (ft³/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 prior to 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, etc. 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*) Fresh water 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, etc.) 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 to simply 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.

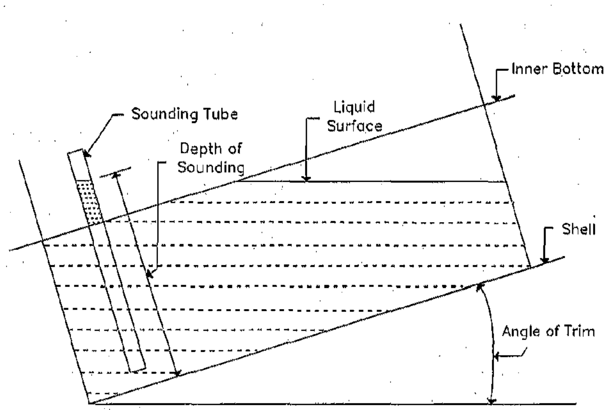


FIG. 10 Tank Containing Entrapped Air

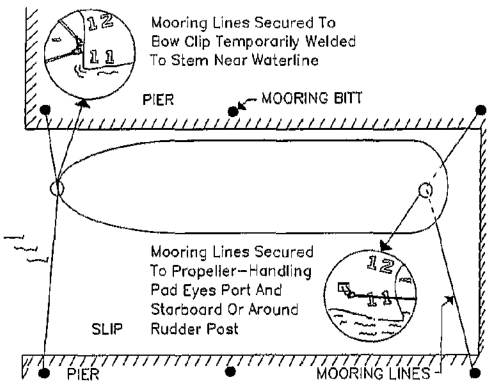


FIG. 11 The Preferred Mooring Arrangement

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 shore side 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. Prior to 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 in order 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

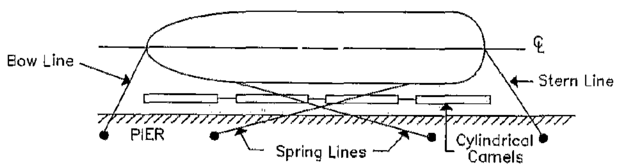


FIG. 12 An Acceptable Alternate Mooring Arrangement

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 due to 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, etc. connected to shore should be at a minimum, and kept slack at all times.

5.4 *List and Trim*—In order 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 ½° 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.

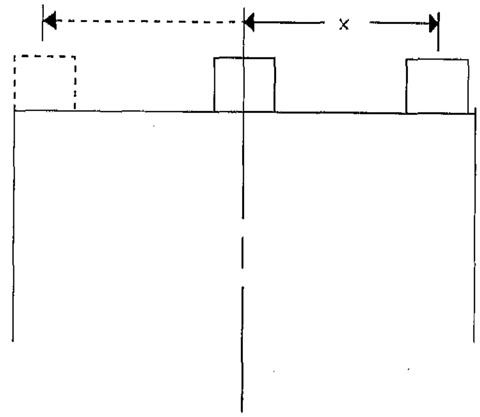


FIG. 13 Movement of the Test Weights

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;

$$GM = KM - KG \quad (3)$$

5.5.1.4 Estimate the total weight (W) required by the following formula:

$$W = \frac{GM\,(\tan\theta)\,\text{displ}}{x} \quad (4)$$

where θ 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 prior to 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 the measured weight is accurate. The time since weighing depends on the construction of the weight.

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 prior to 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 prior to 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.

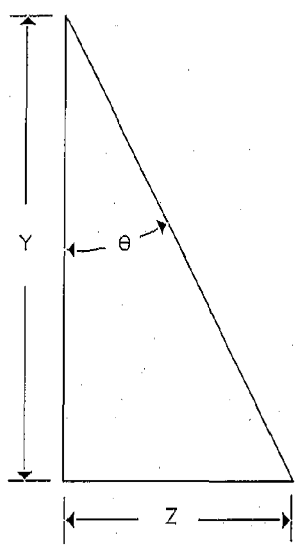
5.8 *Additional Requirements:*

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



$\tan \theta = Z/Y$
$\tan 4° = 6 \text{ in.}/Y$
$Y = 6 \text{ in.}/\tan 4°$
$Y = 6 \text{ in.}/0.0699$
$Y = 87 \text{ in.}$
$\tan 3° = 6 \text{ in.}/Y$
$Y = 6 \text{ in.}/\tan 3°$
$Y = 6 \text{ in.}/0.0524$
$Y = 114 \text{ in.}$
$\tan 2° = 6 \text{ in.}/Y$
$Y = 6 \text{ in.}/\tan 2°$
$Y = 6 \text{ in.}/0.0349$
$Y = 172 \text{ in.}$

FIG. 14 Angle of Inclination versus Pendulum Length

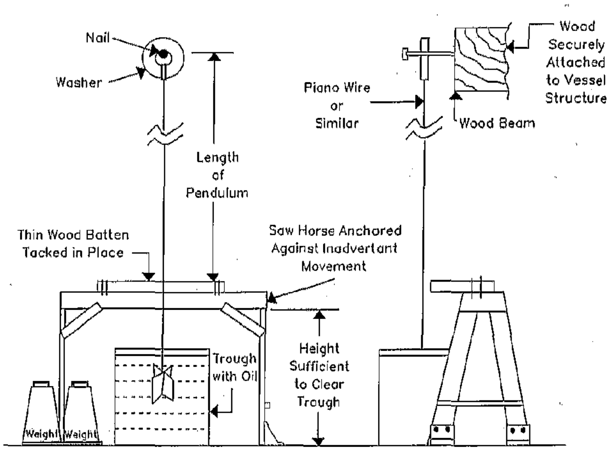


FIG. 15 Typical Satisfactory Pendulum Arrangement

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, etc.,

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, etc.,

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, etc., 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, etc., 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 accurately record freeboards and drafts,

(*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 which 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.

(3) When estimating weights to be relocated:
- estimate high for items to be relocated to a higher point in the vessel,
- estimate low for items to be relocated to a lower point in the vessel.

7.1.2 *Freeboard/Draft Readings:*

7.1.2.1 Take freeboard/draft readings to establish the position of the waterline in order 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 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

TABLE 1 Typical Survey Entries

Items to Be Removed			
Item	*Weight, lb*	*Vertical Center*	*Longitudinal Center*
Inclining weight No. 1	2400	3 ft above main deck	4.5 ft aft frame 50
Inclining weight No. 2	2640	3 ft above main deck	frame 50
Inclining Weight No. 3	2500	3 ft above main deck	4.5 ft forward frame 50
Inclining Weight No. 4	2350	3 ft above main deck	frame 51
Two men	370	3 ft above main deck	frame 63
Two men	370	3 ft above main deck	frame 90
Pendulum No. 1 (total setup and one man)	240	2.8 ft above bottom at centerline	3 ft forward of aft engine room bulkhead
Fuel oil tank No. 3P 8 ft 8 in. sounding	[A]	[A]	[A]
Potable water tk No. 1C 9 ft 3 in. sounding	[A]	[A]	[A]

Items to Be Added			
Item	*Weight, lb*	*Vertical Center*	*Longitudinal Center*
Radio	200	5 ft above pilot deck	2 ft aft forward pilot house bulkhead
Antenna	85	15 ft above top of pilot house	frame 20
Towing cable	800	2.5 ft above main deck	8 ft forward frame 85
Rescue boat	120	4 ft above main deck	frame 60

Items to Be Relocated					
Item	*Weight*	*From*		*To*	
		Vertical	*Longitudinal*	*Vertical*	*Longitudinal*
Liferaft	300	main deck	frame 50	01 deck	frame 65
Fire pump	220	main deck	frame 65	2 ft above shell	frame 40

[A] Can be determined later by the naval architect from drawings or sounding tables, or both.

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. In order 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:

$$d = D + t - f \quad (5)$$

See Fig. 17. If the freeboard is measured from the top of the bulwark to the waterline:

$$d = D + t + b - f \quad (6)$$

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 Prior to any weight movements, check the following:

(*a*) Check the mooring arrangement to ensure that the vessel is floating freely. (Do this just prior to 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.

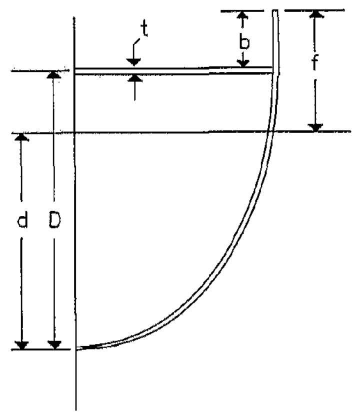
7.1.3.2 Run a plot during the test to ensure that acceptable data is being obtained. Typically, the abscissa of the plot will be heeling moment (weight times distance) and the ordinate will be the tangent of the heel angle (deflection of the pendulum divided by the length of the pendulum).

7.1.3.3 The standard test employs 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.

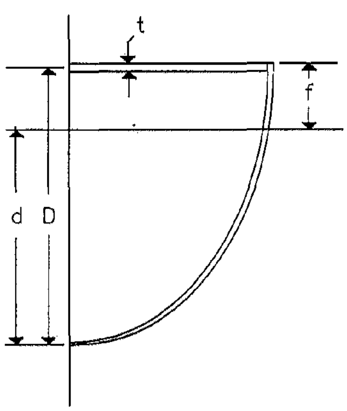
7.1.3.5 Once everything and everyone is in place, obtain the zero position and conduct the remainder of the experiment as quickly as possible, while maintaining accuracy and proper procedures, in order to minimize the possibility of a change in environmental conditions during the test.

7.1.3.6 Prior to 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 doesn't 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



NOTE—where:
D = molded depth
d = molded draft
f = freeboard reading
t = deck thickness
b = bulwark height

FIG. 17 Converting Freeboards (Measured to Top of Bulwark) into Molded Drafts



NOTE—where:
D = molded depth
d = molded draft
f = freeboard reading
t = deck thickness
b = bulwark height

FIG. 16 Converting Freeboards (Measured to the Main Deck) into Molded Drafts

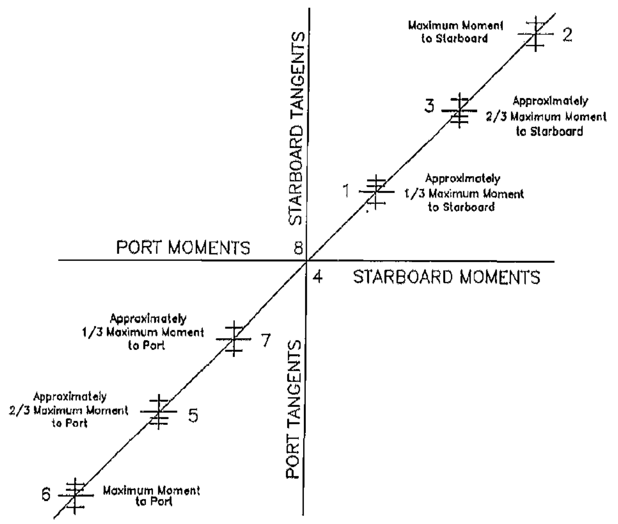


FIG. 18 Acceptable Spread of Test Points On Incline Plot

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, etc., 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 and readings	nearest 1/16 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.

ANNEXES

(Mandatory Information)

A1. TO RECEIVE UNITED STATES COAST GUARD APPROVAL OF THE STABILITY TEST ON COMMERCIAL VESSELS THE FOLLOWING ADDITIONAL REQUIREMENTS SHOULD BE FOLLOWED

(In Amplification of the Regulations)

A1.1 *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 prior to the test. The MSC will make arrangements for an acceptable representative to witness the test.

A1.1.1 *Details of Notification*—Written notification should provide the following information:

A1.1.1.1 Identification of the vessel by name and shipyard hull number, if applicable.

A1.1.1.2 Date, time, and location of the test.

A1.1.1.3 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.

A1.1.1.4 *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.)

A1.1.1.5 Approximate trim.

A1.1.1.6 Condition of tanks.

A1.1.1.7 Estimated weights to deduct, to complete, and to relocate in order to place the vessel in its true light ship condition.

A1.1.1.8 Detailed description of any computer software to be used to aid in calculations during the inclining.

A1.1.1.9 Name and phone number of the person responsible for conducting the test.

A1.2 Alternate mooring arrangements will be considered if submitted for review prior to 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 prior to departure from the office and an alternate date scheduled.

A1.5 An estimate of work items which 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 Prior to 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,[2] 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

[2] *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.

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 which 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. Figure A2.1 gives an example of an acceptable plot.

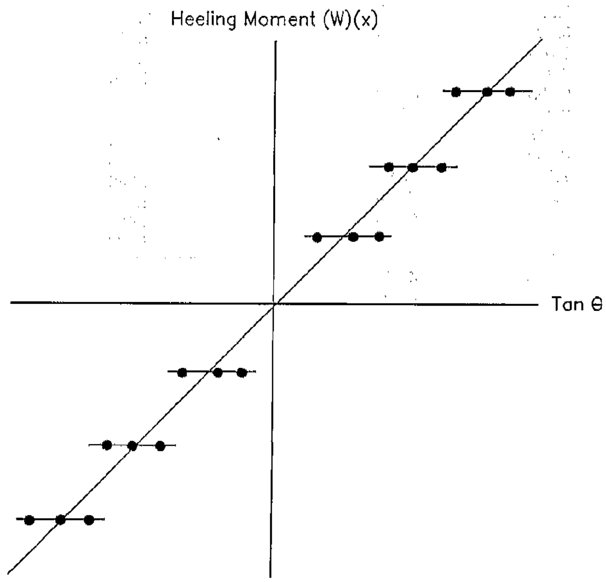


FIG. A2.1 Acceptable Orientation for Incline Plots on U.S. Navy Vessels

A3. CONVERSION TABLES FOR LIQUIDS

A3.1 Tables A3.1 and 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[A]

Degrees API	Specifiction Gravity	bbl/ton	ft^3/ton
10	1.0000	6.404	35.96
11	0.9930	6.449	36.21
12	0.9861	6.494	36.46
13	0.9792	6.540	36.72
14	0.9725	6.585	36.97
15	0.9659	6.630	37.22
16	0.9593	6.776	37.48
17	0.9529	6.720	37.73
18	0.9465	6.766	37.99
19	0.9402	6.811	38.24
20	0.9340	6.856	38.50
21	0.9279	6.901	38.75
22	0.9218	6.947	39.01
23	0.9159	6.992	39.26
24	0.9100	7.037	39.51
25	0.9042	7.082	39.76
26	0.8984	7.128	40.02
27	0.8927	7.174	40.28
28	0.8871	7.219	40.53
29	0.8816	7.264	40.78
30	0.8762	7.309	41.04

[A] Conversion Formula:

$$\text{Specific gravity} = \frac{141.5}{(131.5 + B)}$$

where B = degrees API.

TABLE A3.2 Water

Specific Gravity	ft^3/ton
0.999	35.99
1.000	35.96
1.001	35.92
1.002	35.88
1.003	35.85
1.004	35.81
1.005	35.78
1.006	35.74
1.007	35.71
1.008	35.67
1.009	35.63
1.010	35.60
1.011	35.56
1.012	35.53
1.013	35.49
1.014	35.46
1.015	35.42
1.016	35.39
1.017	35.35
1.018	35.32
1.019	35.28
1.020	35.25
1.021	35.22
1.022	35.18
1.023	35.15
1.024	35.11
1.025	35.08
1.026	35.04
1.027	35.01
1.028	34.98

APPENDIXES

(Nonmandatory Information)

X1. STABILITY TEST CHECK LIST

X1.1 *Pre-Inclining:*

1. ________ Vessel is complete or nearly so.
(*a*) No major structural sections or major items of equipment 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 1/8 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 calculations.

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 (5) 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 (3); 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 required 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 accidentally 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 accidentally 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 (3) to each side of the reference position.
(*b*) Deflection of the pendulums at maximum moment should be at least six (6) inches to each side of the initial position.
(*c*) Maximum angle of heel should not be greater than four (4) degrees; value of tangent must be less than 0.06993. Typical angle of heel should be between two (2) and three (3) degrees.
(*d*) Moment equals weight times distance moved; calculated and summed for all weights moved for each movement.
(*e*) Tangent equals pendulum deflection divided by pendulum 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 θ 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 underlayments;
(*h*) Cables for winches;
(*i*) Lines and hawsers;
(*j*) Engineroom 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;
(*q*) Masts and navigation lights.

3. ________ Typical weights to deduct:

(*a*) Inclining weights and pendulum set-up;
(*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;
(*g*) Dunnage.

4. ________ Typical weights to relocate:

(*a*) Paneling;
(*b*) Lifesaving equipment;
(*c*) Fenders and mooring equipment;
(*d*) Fire extinguishing equipment.

X2. SAMPLE DATA SHEETS

________ Stability Test Rough Data ________

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

Description	Weight	Vertical Center	Longitudinal Center	Transverse Center (if needed)

TANKS:

Description	Location	Sounding or Ullage	Specific Gravity/Density

FIG. X2.2 Items to be Added

Items to Be Removed

Description	Weight	Vertical Center	Longitudinal Center	Transverse Center (if needed)

TANKS:

Description	Location	Sounding or Ullage	Specific Gravity/Density

FIG. X2.3 Items to be Removed

Items to be Relocated

Description	Weight		From			To	
		Vertical Center	Longitudinal Center	Tranverse Center (if needed)	Vertical Center	Longitudinal Center	Tranverse Center (if needed)

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
$d = D + t + b - f$

Location		*f*	*t*	*D*	*b*	d
1.	P					
	S					
2.	P					
	S					
3.	P					
	S					
4.	P					
	S					
5.	P					
	S					
6.	P					
	S					
7.	P					
	S					
8.	P					
	S					

Draft Mark Readings

Location	Reading	Location	Reading
	P		P
	S		S
	P		P
	S		S
	P		P
	S		S

FIG. X2.5 Freeboard Readings

Ship at Time of Stability Test—Condition 0

Pendulums		Weight		Distance from Initial Positions		Moment	Total Inclining Moment		Pendulum Deflections			Tangents	
No. Location	Length to Batten	No.		Port	Starboard		Port	Starboard	No.	Port	Starboard	Port	Starboard
	Inches		Tons	Feet	Feet	Ft-Tons	Ft-Tons	Ft-Tons		Inches	Inches		
1st		1st Trial							1st 2d 3d				
2d		2d Trial							1st 2d 3d				
3d		3d Trial							1st 2d 3d				
		4th Trial							1st 2d 3d				
		5th Trial							1st 2d 3d				
		6th Trial							1st 2d 3d				
		7th Trial							1st 2d 3d				
		8th Trial							1st 2d 3d				

Inclining Weights

Location ____________

Description ____________

Weight		Initial Position	
No.		Port	Starboard
	Tons	Feet	Feet

FIG. X2.6 Condition 0—Preliminary Report

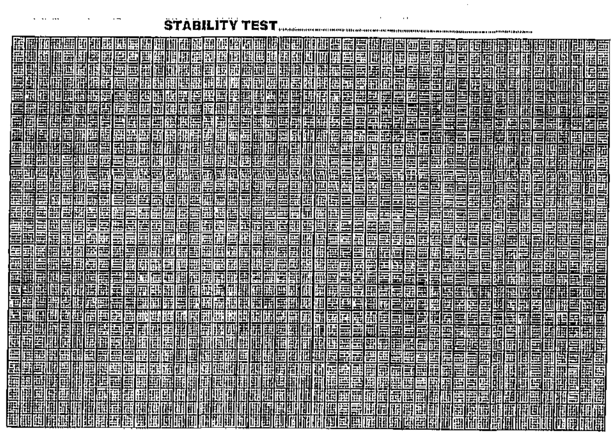


FIG. X2.7 Stability Test Graph—Preliminary Results

X3. STABILITY TEST DATA

Stability Test Data

Official Number ________________
Gross Tons ________________

DESCRIPTION OF VESSEL ________________

Type ________________
Builder ________________
Hull Number ____________ Date Built ____________
Hull ________________
____
____

Machinery ________________
____
____
____

Classed By ______ Inspected ☐ Safety Certificate ☐ Load Line ☐
Route: Ocean ☐ Coastwise ☐ Great Lakes ☐ Bays ☐ Rivers ☐
Specify Route, If Limited ________________

Owner ________________
Owner's Address ________________

Vessel Inclined At ________________
Date ________________ Time ________________
Test Requested By ________________

Plans Furnished By ________________
Offsets Measured By ________________
Curves of Form Computed By ________________

Test Conducted By ________________
Stability Calculations Made By ________________
Sister Vessels ________________

FIG. X3.1 Stability Test Data

Stability Test

Principal Dimensions

Length over all ________________ ft ______ in. (______ ft)
Length between perpendiculars which are at the extremities of ____________ waterline ____________ ft ______ in. (______ ft)
Length between draft marks, ____________ condition ____________ ft ______ in. (______ ft)
Breadth, extreme, at ____________ feet above base ____________ ft ______ in. (______ ft)
Breadth, molded, amidships at ____________ feet above base ____________ ft ______ in. (______ ft)
Breadth at load water line ________________ ft ______ in. (______ ft)
Depth amidships, from ____________ to ____________ ft ______ in. (______ ft)
Apparent full-load mean draft for stability { molded base ________________ ft ______ in. (______ ft)
{ bottom of keel ________________ ft ______ in. (______ ft)
Displacement, sea water, tons (2240 lb), at above full-load draft ________________ tons
Freeboard amidships at above full-load draft ________________ ft ______ in. (______ ft)
Freeboard at low point of sheer (____________ feet aft of amidships) ________________ ft ______ in. (______ ft)
Location of ports, in hull, which may affect stability ________________

General Information

Names and duties of official observers ________________
Designers represented by ________________
Builders represented by ________________
Owners represented by ________________
Weather, tide, and mooring conditions ________________
Condition of ship as to completeness and as to water in boilers, machinery, and bilges ________________

FIG. X3.2 Stability Test—Principle Dimensions

Stability Test

All tons used in this calculation are of ________ lb

Ship at Time of Stability Test—Condition 0

Sketch Showing Hog, Sag, Trim, Drag, and Location of Draft Marks, Freeboards, and Perpendiculars

Draft from draft marks when inclined
- Forward ____________ ft ________ in.
- Aft ____________ ft ________ in.
- Amidships
  - Port ________ ft ________ in.
  - Starboard ________ ft ________ in.

Distance between "curves of form" perpendiculars ____________ ft

Bottom of keel below base line ____________ in.

Molded / Keel drafts corrected to "curves of form" perpendiculars for use in calculations
- Forward ____________ ft
- Aft ____________ ft
- Mean of amidships P and S __ ft

Mean of forward and after drafts ____________ ft

Hog or sag ____________ ft

Trim forward, aft ____________ ft

Longitudinal center of floatation forward, aft ____________ ft

Molded / Keel draft at center of flotation ____________ ft

Molded / Keel draft at L.C.F. corrected for hog or sag ______ ft

Total displacement at above draft F.W., S. W. ____________ tons

Specific gravity of water ________ equals ________ ft^3/ton

Total displacement corrected for density ____________ tons

FIG. X3.3 Stability Test Sketch—Condition 0

Ship at Time of Stability Test—Condition 0

Pendulums No.	Location	Length to Batten (in.)
1st		
2d		
3d		

Inclining Weights

Location ____________

Description ____________

Weight No.	tons	Initial Position Port (ft)	Initial Position Starboard (ft)

Trial	Weight No.	Weight (tons)	Distance from Initial Positions Port (ft)	Distance from Initial Positions Starboard (ft)	Moment (ft-tons)	Total Inclining Moment Port (ft-tons)	Total Inclining Moment Starboard (ft-tons)	Pendulum Deflections No.	Pendulum Deflections Port (in.)	Pendulum Deflections Starboard (in.)	Tangents Port	Tangents Starboard
1st Trial								1st				
								2d				
								3d				
2d Trial								1st				
								2d				
								3d				
3d Trial								1st				
								2d				
								3d				
4th Trial								1st				
								2d				
								3d				
5th Trial								1st				
								2d				
								3d				
6th Trial								1st				
								2d				
								3d				
7th Trial								1st				
								2d				
								3d				
8th Trial								1st				
								2d				
								3d				

FIG. X3.4 Condition 0—Final Report

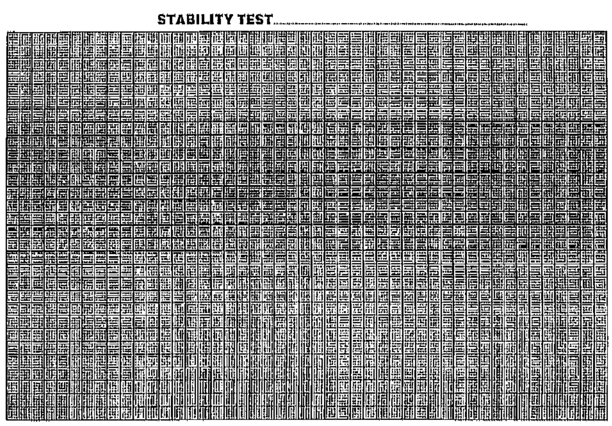


FIG. X3.5 Stability Test Graph—Final Results

Stability Test

Ship at Time of Stability Test—Condition 0

	From Hydrostatic Curves	From Independent Calculation
Corrected displacement	______ tons	______ tons
Mean virtual metacentric height obtained from plot of inclining moments versus tangents of angles of heel— $\frac{\text{moment}}{\text{displacement} \times \text{tangent}}$	______ ft	______ ft
Correction for free surface	______ ft[A]	______ ft
Mean metacentric height G. M. =	______ ft	______ ft
Transverse metacenter above the base line corresponding to draft at L. C. F. (corrected for hog or sag)	______ ft[B]	
Transverse metacenter above the base line corrected (for trim, and hog or sag)	______ ft	
C. G. above base line	______ ft	______ ft (from figure)
Longitudinal metacenter above C. G.	______ ft	
Moment to alter trim 1 foot, $\frac{\text{Longl. GM} \times \Delta}{L}$	______ ft-tons	
Trim by stern, bow	______ ft[B]	
Trimming lever = $\frac{\text{Trim} \times \text{moment to trim}}{\text{displacement}}$	______ ft	
L.C.B. forward, aft of amidships, which is ____ ft forward, aft of frame No.____	______ ft	
C. G. forward, aft of amidships	______ ft	______ ft (from figure)

Period of complete roll ______ s

Apparent radius of gyration of vessel—k = $\frac{T\sqrt{GM}}{1.108}$ ______ ft

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. X3.6 Stability Test Results at Condition 0 from Hydrostatic Curves and Independent Calculation

Stability Test

Data for Tanks						C. G. Above base		C. G. Above from M. P.			
Liquid	Sounding	Net Inertia of Free Surface	Inertia, ft^3-ton	Items	Weight, tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons

FIG. X3.7 Stability Test—Data for Tanks

Stability Test

Ship Light—Condition I

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.

List of Major Equipment, etc., Included in Condition I as Shown
Ballast, boats, rafts, cargo booms, anchors, guns, armor, etc.

Items	Weight, tons	C.G. Above Base, ft	*C.G. from M.P.* Feet Forward	*C.G. from M.P.* Feet Aft
Fixed Ballast				

Items	Displacement and Weight	C. G. Above Base		C.G. Above from M. P.			
	tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons
Ship in Condition 0							
Weight to Complete							
Weight to Relocate							
Weight to Remove							
Ship in Condition I							

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

Longitudinal metacenter above C.G. at L.C.F. draft ________ ft
Moment to alter trim 1 foot at L.C.F. draft, $\frac{\text{longl GM} \times \Delta}{L}$ ________ ft-tons
C.B. of ship on even keel at L.C.F. draft, aft, forward f ⊕ ________ ft
C.G. aft, forward of amidships ________ ft
Trimming lever ________ ft
Trim, aft, forward— $\frac{\text{displacement} \times \text{lever}}{\text{moment to trim}}$ ________ ft

L.C.F. aft, forward of amidships ________ ft
Difference between L.C.F. and amidships draft ________ ft
Molded draft amidships ________ ft
Draft on draft marks, forward ________ ft
Draft on draft marks, aft ________ ft

FIG. X3.8 Ship Light—Condition I

Stability Test

Ship in Condition ____________

Description of Condition	Items	Displacement and Weight	C. G. Above Base		C. G. Above from M. P.			
		tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons
______	Ship in Condition ______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	Total ______	______	______	______	______	______	______	______

______ 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 free surface [corrected for trim / uncorrected for trim] G.M. ______ ft

Correction for free surface Metacentric height, corrected for free surface [corrected for trim / uncorrected for trim] G.M. ______ ft

Longitudinal metacenter above C.G. at L.C.F. draft ______ ft

Moment to alter trim 1 foot at L.C.F. draft, $\frac{\text{longl GM} \times \Delta}{L}$ ______ ft-tons

C.B. of ship on even keel at L.C.F. draft, aft, forward of amidships ______ ft

C.G. aft, forward of amidships ______ ft

Trimming lever ______ ft

Trim, aft, forward—$\frac{\text{displacement} \times \text{lever}}{\text{moment to trim}}$ ______ ft

Longitudinal center of floatation, aft, forward of amidships ______ ft

Difference between L.C.F. and amidships draft ______ ft

Molded draft amidships ______ ft

Draft on draft marks, forward ______ ft

Draft on draft marks, aft ______ ft

FIG. X3.9 Stability Test—Condition Description

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

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM F1323: Standard Specification for Shipboard Incinerators

CFR Section(s): 46 CFR 63.25-9

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1323 – 98

An American National Standard

Standard Specification for Shipboard Incinerators[1]

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 (ϵ) 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 Appendixes Appendix X1-Appendix X5.

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 specification does not cover emissions requirements.

1.8 *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.* See 4.8.

2. Referenced Documents

2.1 *ASTM Standards:*

F 1322 Guide for Selection of Shipboard Incinerators[2]

2.2 *ANSI Standard:*

B 31.1 Power Piping[3]

ANSI/NFPA No. 70 National Electrical Code[3]

Article 430-7[3]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section I, Power Boilers[4]

Section IX, Welding and Brazing Qualification[4]

2.4 *Underwriter's Laboratory Standards:*

UL 506 Standard for Specialty Transformers[5]

UL 814 Standard for Gas-Tube Signs and Ignition Cables[5]

2.5 *Safety of Life at Sea Convention:*

SOLAS 74 International Convention for the Safety of Life at Sea[3]

2.6 *Other Documents:*

International Convention for the Preventing of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78)[6]

NOTE 1—Incinerators designed and manufactured in accordance with alternative standards must show compliance with this specification.

3. Terminology

3.1 *Definitions:*

3.1.1 *cargo-associated waste*—all materials that have become wastes 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 wastes, sewage, and wastes 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 wastes, 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

[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.06 on Marine Environmental Protection.

Current edition approved April 10, 1998. Published October 1998. Originally published as F 1323 - 90. Last previous edition F 1323 - 90.

[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[5] Available from Underwriter's Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

[6] Available from the International Maritime Organization, 4 Albert Embankment, London SE1 7SR, UK.

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 *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, and fishing gear, and so forth. These facilities may be designed to use or not to use the heat energy produced.

3.1.8 *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.

3.1.9 *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.

3.1.10 *operational wastes*—all cargo-associated wastes and maintenance waste (including ash and clinkers) and cargo residues defined as garbage in 3.1.6.

3.1.11 *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.

3.1.12 *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.

3.1.13 *waste*—useless, unneeded, or superfluous matter which is to be discarded.

4. Materials and Manufacture

4.1 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.

4.2 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.

4.3 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.

4.4 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.

4.5 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 5.1).

4.6 Incinerating systems shall be designed such that corrosion will be minimized on the inside of the systems.

4.7 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.

4.8 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.

4.8.1 For instance, where charging is carried out by hand, a charging lock may be provided that ensures that the charging space is isolated from the fire box as long as the filling hatch is open.

4.8.2 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.

4.9 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.

4.10 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.

4.11 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.

4.12 *Electrical Requirements*:

4.12.1 *General*—Installation requirements shall apply to controls, safety devices, and burners on incinerators.

4.12.1.1 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 potential. This disconnecting means shall be an integral part of the incinerator or adjacent to it (see 6.1).

4.12.1.2 All uninsulated live metal parts and all rotating or moving parts that may cause injury shall be guarded to avoid accidental contact.

4.12.1.3 The electrical equipment shall be so arranged so that failure of this equipment will cause the fuel supply to be shut off.

4.12.1.4 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.

4.12.1.5 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.

4.12.1.6 All electrical components and devices shall have a voltage rating commensurate with the supply voltage of the control system.

4.12.1.7 All electrical devices shall be at least NEMA Type 2 (Driptight). Electric equipment exposed to the weather shall be at least NEMA Type 4.

4.12.1.8 All electrical and mechanical control devices shall be of a type tested and accepted by a nationally recognized testing agency.

4.12.1.9 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.

4.12.2 *Overcurrent Protection*:

4.12.2.1 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.

4.12.2.2 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.

4.12.2.3 Overcurrent protection devices shall be accessible and their function shall be identified.

4.12.3 *Motors*:

4.12.3.1 Motors exposed to dripping or spraying oil or water shall be of drip-proof construction. All motors shall be fully guarded as installed.

4.12.3.2 Motors shall be provided with a corrosion-resistant nameplate specifying information in accordance with NEC, Article 430-7.

4.12.3.3 Motors shall be provided with running protection by means of integral thermal protection, by overcurrent devices, or a combination of both in accordance with manufacturer's instructions that shall be based on the requirements of National Electrical Code, NFPA No. 70.

4.12.3.4 Motors shall be rated for continuous duty and shall be designed for an ambient temperature of 122°F (50°C) or higher.

4.12.3.5 All motors shall be provided with terminal leads or terminal screws in terminal boxes integral with, or secured to, the motor frames.

4.12.4 *Ignition System*:

4.12.4.1 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.

4.12.4.2 Ignition transformers shall conform to requirements of the UL Standard 506.

4.12.4.3 Ignition cable shall conform to requirements of the UL Standard 814.

4.12.5 *Wiring*:

4.12.5.1 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 National Electrical Code, NFPA No. 70. All wiring between components shall have copper conductors not less than size No. 18 AWG and constructed in accordance with the National Electrical Code, NFPA No. 70.

4.12.5.2 All electrical wiring shall have a voltage rating commensurate with the voltage of the power supply.

4.12.5.3 Conductors shall be protected from physical damage where appropriate.

4.12.5.4 Conductors shall be sized on the basis of the rated current of the load they supply.

4.12.6 *Bonding and Grounding*:

4.12.6.1 Means shall be provided for grounding the major metallic frame or assembly of the incinerators.

4.12.6.2 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.

4.12.6.3 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.

5. Operating Requirements

5.1 The incinerator system shall be designed and constructed for operation with the following conditions:

Maximum combustion chamber temperature	2190°F (1200°C)
Minimum combustion chamber temperature	1560°F (850°C)
Preheat temperature of combustion chamber	1200°F (650°C)
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 1110°F (600°C) within 5 min after start.	
Prepurge, before ignition	at least four air changes in the chamber(s) and stack, but not less than 15 s
Time between restarts	at least four 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
Incinerator discharge gases	min 6 % O_2 (measured in dry flue gas)

5.2 Outside surface of combustion chamber(s) shall be shielded from contact such that people would not be exposed to extreme heat (maximum 68°F (20°C) above ambient temperature) or direct contact of surface temperatures exceeding 140°F (60°C). Examples for alternatives to accomplish this are a double jacket with an air flow in between or an expanded metal jacket.

5.3 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.

5.4 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 garbage.

5.5 The incinerator shall have instruction plate(s) attached in a prominent location on the unit that clearly addresses the following:

5.5.1 Cleaning ashes and slag from the combustion chamber(s) and cleaning of combustion air openings before starting the incinerator (where applicable).

5.5.2 Operating procedures and instructions.

5.6 To avoid the buildup of dioxins, the flue gas should be shock-cooled to a maximum 660°F (350°C) within 2.5 m from the combustion chamber flue gas outlet.

6. Operating Controls

6.1 The entire unit shall be disconnected from all sources of electricity by means of one disconnect switch located near the incinerator (see 4.12.1.1).

6.2 There shall be an emergency stop switch located outside the compartment which 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.

6.3 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.

6.3.1 *Safety Thermostat/Draft Failure*:

6.3.1.1 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.

6.3.1.2 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.

6.3.1.3 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.

6.3.2 *Flame Failure/Fuel Oil Pressure*:

6.3.2.1 The incinerator shall have a flame safeguard control consisting of a flame-sensing element and associated equipment for shut down 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.

6.3.2.2 The flame safeguard control shall be capable of closing the fuel valves in not more than 4 s after a flame failure.

6.3.2.3 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.

6.3.2.4 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.

6.3.2.5 Flame safeguard controls of the thermostatic type, such as stack switches and pyrostats operated by means of an open bimetallic helix, are prohibited.

6.3.2.6 If fuel oil pressure drops below that set by the manufacturer, a failure and lock out of the program relay shall result. This also applies to a sludge oil burner. (Applies where pressure is important for the combustion process or where a pump is not an integral part of the burner.)

6.3.3 *Motor Overload*—All motors shall be protected in all phases by a thermal overload relay or circuit breaker with thermal overload protection which must be reset manually (see 4.12.3.3).

6.3.4 If there is a loss of power to the incinerator control/alarm panel (not remote alarm panel), the system shall shut down.

6.4 *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.

6.5 *Alarms*:

6.5.1 When a failure occurs, an audible alarm shall be automatically sounded. A visible indicator shall show what caused the failure. (Alarm may be provided by the user and indicator may cover more than one fault condition.)

6.5.2 Means shall be provided to silence the audible alarm. The visible indicators shall be designed so that, where failure is a safety related shutdown, manual reset is required.

6.6 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.

7. Other Requirements

7.1 *Documentation*—A complete instruction and maintenance manual with drawings, electric diagrams, spare parts list, and so forth shall be furnished with each incinerator.

7.2 *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.

7.3 *Incinerator*:

7.3.1 Incinerators are to be fitted with a pilot burner 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 6.3.1.3).

7.3.2 A driptray is to be fitted under each burner and under any pumps, strainers, and so forth that require occasional examination.

8. Tests

8.1 *Prototype Tests*—An operating test for the prototype of each design shall be conducted, with a test report completed indicating results of all tests. The tests 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. Tests shall include those described in8.3.

8.2 *Factory Tests*—For each unit, if preassembled, an operating test 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. Tests shall include those described in 8.3.

8.3 *Installation Tests*—An operating test 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 5.1 shall be verified at the time of the installation test.

8.3.1 *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.

8.3.2 *Limit Controls*—Shutdown as a result of the operation of the limit controls shall be verified.

8.3.2.1 *Oil Pressure Limit Control*—The lowering of the fuel oil pressure below the value required for safe combustion shall initiate a safety shutdown.

8.3.2.2 *Other Interlocks*—Other interlocks provided shall be tested for proper operation as specified by the unit manufacturer.

8.3.3 *Combustion Controls*—The combustion control shall be stable and operate smoothly.

8.3.4 *Programming Controls*—Programming controls shall be verified as controlling and cycling the unit in the intended manner. Proper prepurge, ignition, postpurge, and modulation shall be verified. A stopwatch shall be used for verifying intervals of time.

8.3.5 *Fuel Supply Controls*—The satisfactory operation of the two fuel control solenoid valves for all conditions of operation and shutdown shall be verified.

8.3.6 *Low-Voltage Test*—A low-voltage test 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.

8.3.7 *Switches*—All switches shall be tested to verify proper operation.

9. Inspections

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 an incinerator has been constructed in accordance with this specification shall be provided (by letter, certificate, or in the instruction manual).

11. Product Marking

11.1 Each incinerator shall be permanently marked indicating:

11.1.1 Manufacturer's name or trademark.

11.1.2 Style, type, model, or other manufacturer's designation for the incinerator.

11.1.3 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, kilocalories per hour.

11.1.4 ASTM designation of this specification (F 1323).

12. Quality Assurance

12.1 Incinerators shall be designed, manufactured, and tested in a manner that ensures they meet the requirements of this specification.

12.2 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 standard designation that does not meet the requirements herein (see Certification).

APPENDIXES

(Nonmandatory Information)

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 shall 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 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 775°F (413°C).

X4. DESIGN FOR FUTURE RETROFITS OF AIR EMISSION CONTROL EQUIPMENT

X4.1 Though not a requirement, it is recommended that incinerators be designed 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.

X4.3 Note that emission control equipment is unnecessary if the incinerator is only operated at sea, not in port or in coastal waters.

X5. SPARK ARRESTORS

X5.1 The incinerator should be so constructed or so equipped as not to permit from the exhaust the passage of spheres having a diameter larger than ½ in. (13.7 mm) nor block the passage of spheres having a diameter of less than ⅜ in. (9.5 mm).

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.

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CERTIFICATE

By Authority Of
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Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1471 – 93

Standard Test Method for Air Cleaning Performance of a High-Efficiency Particulate Air Filter System[1]

This standard is issued under the fixed designation F 1471; 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 test method covers the procedure and equipment for measuring the penetration of test particles through high-efficiency particulate air (HEPA) filter systems using a laser aerosol spectrometer (LAS). This test method provides the capability of evaluating the overall effectiveness of HEPA filter systems consisting of one or two filter stages.

1.2 The aerosols used for testing have a heterodisperse size distribution in the submicrometer diameter range from 0.1 to 1.0 μm.

1.3 The purpose for conducting in-place filter testing by this test method is in the ability to determine penetration of multi-stage installations, without individual stage tests. Particle penetration as low as 10^{-8} can be measured by this test method. Also, the LAS provides a measure of penetration for discrete particle sizes.

1.4 Maximum penetration for an installed HEPA filter system is 5×10^{-4} for one filter stage, and 2.5×10^{-7} for two stages in series is recommended.

NOTE 1—Acceptance penetration criteria must be specified in the program, or owners specifications. The penetration criteria suggested in this test method is referenced in Ref (**1**).[2]

1.5 The values stated in SI units are to be regarded as the standard.

1.6 *This standard does not purport to address all of the safety problems, 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 Note 2.

2. Referenced Documents

2.1 *ASTM Standards:*

F 328 Practice for Determining Counting and Sizing Accuracy of an Airborne Particle Counter Using Near-Monodisperse Spherical Particulate Materials[3]

2.2 *Military Standard:*

MIL-STD 282 Military Standard Filter Units, Protective Clothing, Gas Mask Components, and Related Products: Performance Test Method[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *diluter*—a device used to reduce the aerosol particle concentration to eliminate coincidence counting is in the LAS.

3.1.2 *dilution ratio*—the ratio of the undiluted aerosol particle concentration entering the diluter to the diluted portion of the particle concentration. Because diluters have inherent particle losses that may vary according to the particle size, the dilution ratio may not be constant with respect to size.

3.1.3 *laser aerosol spectrometer (LAS)*—a precision particle detector that allows single particle counting and sizing by the amount of scattered light from individual particles, where the signals can be grouped into categories corresponding to particle size.

3.1.4 *penetration*—the number of particles passing through the filter stage, to the number of particles challenging the upstream side of the filter stage. The penetration, or the challenge aerosol, may be associated for each particle size of interest.

4. Summary of Test Method

4.1 A challenge aerosol produced by Di(2-Ethylhexyl) Sebacate (DOS) or Di(2-Ethylhexyl) Phthalate (DOP) is injected upstream of the filter system and allowed to mix with the airstream. Using a LAS, samples of the aerosol are collected from the airstream through probes, both upstream and downstream of the filter system. With this test method, the penetration of the filter system can be calculated either as a function of particle size, or in a particular size of interest. Due to high particle concentrations that may be required to evaluate the performance of HEPA filter systems, it may become necessary to dilute the upstream sample to avoid errors due to coincidence counting by the LAS.

4.2 If a diluter is required, the diluter system is calibrated using lower particle counts of the same aerosol and using the LAS for the measurements (refer to Annex A1 for calibration).

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[1] This test method is under the jurisdiction of ASTM Committee D22 on Sampling and Analysis of Atmospheresand is the direct responsibility of Subcommittee D22.09on ISO TAG for ISO/TC 146.

Current edition approved Feb. 15, 1993. Published April 1993.

[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] *Annual Book of ASTM Standards*, Vol 10.05.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

4.3 Heterodisperse submicrometer aerosols spanning the diameter range from 0.1 to 1.0 μm are used in the testing.

5. Significance and Use

5.1 This test method describes a procedure for determining the penetration of aerosols through a one- or twostage HEPA filter installation. Testing multiple filter stages as a single unit eliminates the need for: installation of auxiliary aerosol bypass ducts, installation of aerosol injection manifolds between filter stages, and entry of test personnel into contaminated areas. It provides for filter testing without interruption of plant processes and operation of ventilation systems.

5.2 The procedure is applicable for measuring penetrations requiring sensitivities to 0.1 μm.

5.3 A challenge concentration of 2.5×10^5 particles/cm^3(p/cm^3), is required for evaluation of one-filter stage, and 2×10^6 p/cm^3, or about 30 μg/L (assuming unit density), is required to properly evaluate a two-stage HEPA filter system as one unit.

5.4 This test method can determine the penetration of HEPA filters in the particle-size range from 0.1 to 0.2 μm where the greatest penetration of particles is likely to occur.

6. Apparatus

6.1 *LAS*[5]—The LAS is a particle detector for the purpose of sizing and counting single particles in a gas stream. Up to 3000 particles per second (p/s) can be counted with less than 10 % coincidence, or electronic loss at its maximum flow rate. The quantitative particle size distribution shall be a distribution by number, not mass, volume, or surface area.

6.2 The test aerosol should be in the diameter range from 0.1 to 1.0 μm.

6.3 The primary particle-size calibration of the LAS by the manufacturer shall be based on at least three sizes of monodisperse polystyrene latex spheres (PSLs), covering the dynamic range of the LAS. Calibration standards must be traceable to the National Institute of Standards and Technology (NIST).

6.4 Sample flow accuracy through the LAS of ±5 % is required, based on the manufacturer's specifications. (Refer to manufacturer's guide for altitude adjustments of the sample volume.)

6.5 The LAS must have the capability for producing a listing of the particle size distribution over the LAS range. A standard RS-232C interface signal for line printers, tape recorders, and computers is usually provided with the instrument.

6.6 For calibration aerosol having a median size two times the minimum detectable size of the LAS, the relative standard deviation of the particle size distribution indicated by the LAS, shall not be increased more than 10 % over the actual relative standard deviation of the calibration aerosol.

6.7 An aerosol diluter[6] is required to reduce the number of particles of the upstream sample to avoid significant coincidence counting losses in the LAS. The diluter must have minimum particle losses over the size range of interest and that the losses are constant with particle size. Calibration of the diluter is done with the LAS. The diluter calibration procedure is indicated in Annex A2. A schematic diagram of the diluter in calibration mode is shown in Fig. A2.1. The diluter calibration plot is presented in Fig. A2.2. A typical diluter with dimensions is illustrated in Fig. A2.3.

6.8 *Aerosol Generation*[7]—It is required that the generator produce a particle-size distribution covering the diameter range from 0.1 to 1.0 μm. It must have the capability of achieving up to 3000 p/s in gas streams when testing multiple-stage HEPA filter systems.

6.9 For streams where large volumes of aerosol are not required, an air-operated or small gas-thermal generator may be used.

6.10 Injection ports, or manifolds, must be provided for distributing the aerosol uniformly with the gas stream. Upstream and downstream probes are required to extract aerosol samples from inside the filter housing. The location of injection ports and sample collection probes or manifolds must be located in accordance with the requirements in Annex A3.

6.11 It is recommended that sample lines between the LAS, diluter, and the upstream and downstream probes be the same size and material, and the same length as practicable.

7. Reagent and Materials

7.1 *DOP or DOS*[8] is used as the liquid material to form test aerosols.

7.2 *Polystyrene Latex Spheres.*[9]

8. Calibration and Standardization

8.1 Perform the primary calibration of the LAS by the instrument manufacturer or by qualified personnel using acceptable standard methods in accordance with Ref **(2)**. Perform calibrations at regular twelve-month intervals and following any repair or modification of the instrument. Place a label showing the due date of the next calibration on the instrument.

8.2 A check calibration by the operator is recommended periodically if the instrument is used continuously or is moved to a new test location requiring vehicle transportation or rough handling. The calibration check consists of testing the LAS with at least two sizes of PSLs. The LAS must correctly size the calibration aerosols and reproduce the spectral peak to within 0.05 μm. If the instrument cannot be adjusted to within those calibration limits, then it must be returned to the manufacturer for service and calibration. Annex A1 describes a procedure for calibration of the LAS.

8.3 *Aerosol Diluter*—It is recommended that the same aerosol used in the in-place testing be used for diluter calibration. If more than one dilution stage is required, each stage

[5] Laser aerosol spectrometers are available from the following sources: Particle Measuring Systems, Inc., 1815 South 57th Court, Boulder, CO 80301, TSI Incorporated Particle Instruments Group, P.O. Box 64394, St. Paul, MN 55164, and Met One, Inc., 481 California Avenue, Grants Pass, OR 97526.

[6] Available from TSI Incorporated Particle Instrument Group, P.O. Box 64394 St. Paul, MN 55164.

[7] Aerosol generators are available from the following sources: Air Techniques Division of Hamilton Associates, Inc., Baltimore, MD 21207, Particle Measurements Systems, Inc., 1815 South 57th Court, Boulder, CO 80301 (Calibration), and Nuclear Consulting Services, Inc., P.O. Box 29151, Columbus, OH 43229.

[8] Di(2-Ethylhexyl) Phthalate (DOP) and Sebacate (DOS) are available from C.P. Hall Co., Chicago, IL 60635, and Nuclear Consulting Services, Inc., P.O. Box 29151, Columbus, OH 43229.

[9] Available from Duke Scientific Corp., Palo Alto, CA 94303.

must be calibrated independently. A procedure for calibration of the diluter using the LAS is outlined in Annex A2.

9. Procedure

9.1 An example of an in-place filter test system and sampling arrangement is illustrated in Fig. 1. Components include the gas-flow duct, filter housing with filters, the LAS, diluter, and aerosol generator.

9.2 *Aerosol Mixing Uniformity Tests*— Conduct these tests upon completion of initial installation and after any modifications or repair to the filter system. It is not required to conduct these tests each time the in-place test is performed. However, if aerosol mixing and sampling parameters are changed, then new air aerosol mixing uniformity tests are required. Refer to Annex A3 for procedure.

9.3 Measure the airflow of the test gas stream and the resistance across the filter stage following the procedure outlined in Annex A3.

9.4 Establish the arrangement of sample lines between the probes, the diluter, and LAS. Make the upstream and downstream sample lines as equal in length as practicable.

9.5 Because of expected low particle counts that can penetrate HEPA filter systems, it is necessary to measure the non-test particles in the gas stream to serve as background samples. With no aerosol generation and no sample dilution, use the LAS to sample the gas stream from the downstream sample probe only. Collect samples at this location for the same duration as will be required for the test aerosol. The background particle counts may vary depending on external leaks to the filter housing, but should not exceed 30 % of the expected test aerosol. If higher background particles are found than those suggested and if leaks in the filter housing are suspected, they must be plugged before testing can continue.

9.6 Generate the challenge aerosol at the suggested particle concentration, see 5.3.

NOTE 2—**Caution:** Avoid unnecessary loading of the filters by the test aerosols by injecting the aerosols only when ready to perform penetration measurements.

9.7 Collect samples from the upstream probe and establish the challenge particle count. This is accomplished by switching the sample line from the LAS to the diluter. Sampling periods are usually 20 s, refer to Annex A2.

9.8 Purge the sample collection system and zero the LAS before proceeding to the next step in the procedure. The purging procedure is described in A2.1.2 of Annex A2.

9.9 Accumulate two successive samples from the downstream location. Sampling time periods should be selected to yield net particle counts over background of at least 100. A10-min sampling period is usually sufficient. The difference between each set of samples shall not exceed 5 % of the larger count. If penetration of only one filter stage is being measured, shorter sampling times may be used because of higher particle counts. If significant penetration is experienced downstream of one-filter stage and coincidence counting is suspected in the LAS, then the diluter must be used in the sample line. See 6.1 and 6.7.)

10. Calculation

10.1 Calculate the penetration of the filter system for each discrete particle-size. The equation holds for each specific size particle diameter as:

$$P = \frac{C_d - C_b}{C_u D} \quad (1)$$

where:

P = penetration,
C_d = particle counts downstream,
C_b = particle counts of background,
C_u = particle counts upstream, and
D = dilution ratio.

10.2 To calculate the uncertainty of the upstream and downstream penetration measurements, a theoretical value was used in the following equation. The value is based on standard propagation-of-error techniques neglecting covariance terms and using Poisson statistics to estimate uncertainties. The equation is as follows:

$$CV_p = [(PNT_d)^{-1} + (D/(NT_u)) + CV_D{}^2]^{1/2} \quad (2)$$

where:

CV_p = coefficient of variation for penetration,

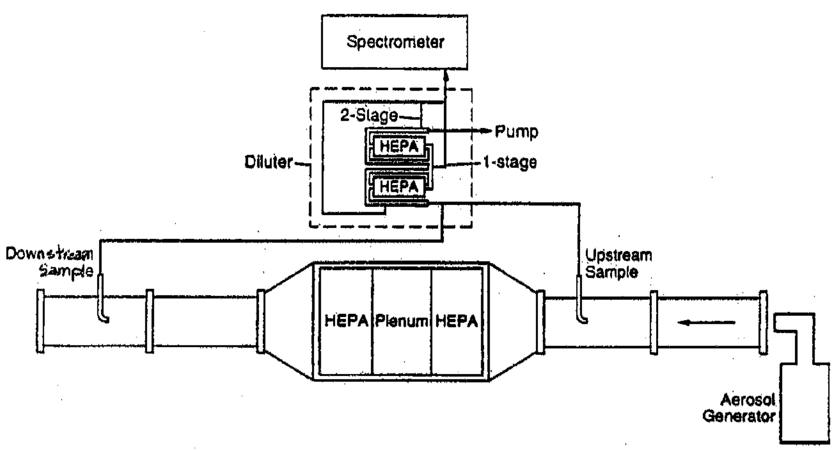

FIG. 1 Schematic Diagram of the In-Place Test Arrangement

P = aerosol number penetration,
N = undiluted upstream count rate, counts/s,
T_d = downstream counting time, s,
D = dilution ratio,
T_u = upstream counting time, s, and
CV_D = coefficient of variation for dilution ratio.

11. Report

11.1 The results of the testing shall contain, at a minimum, the following items:

11.2 Date of testing,

11.3 Identification of the filter system,

11.4 Penetration values, as a function of particle size,

11.5 The size for reporting the interval data may be either the minimum and maximum diameter for each interval or the geometric mean for the interval, and

11.6 Printed names and signatures of test personnel.

12. Precision and Bias

12.1 *Precision*—The precision of this test method for evaluating the air cleaning performance of a high efficiency particle air-filter system is being determined.

12.2 *Bias*—Since there is no reference material suitable for determining the bias for this test method, no statement on bias is being made.

13. Keywords

13.1 aerosol dilution; aerosol generator; average penetration; background particles; challenge aerosols; coincidence; compressed-air nebulizer; dilution ratio; fractional penetration; HEPA; laser aerosol spectrometer; test aerosols

ANNEXES

(Mandatory Information)

A1. LAS CALIBRATION

A1.1 The calibration procedure uses an aerosol having all particles of one size. Polystyrene latex spheres, (PSLs) are generated using a compressed-air nebulizer. The nebulizer is contained in a metal box with two chambers for diluting and drying the aerosol which contain an air-pressure regulator, dilution air control valve, and rotameter.

A1.2 A schematic view of the calibration generator is shown in Fig. A1.1. The aerosol generator must be connected to a compressed-air source that will allow the generator's pressure regulator to deliver 250 cm^3/s at standard temperature and pressure of air at 69-kPa pressure. The compressed-air source must not deliver any water droplets to the generator. If water is a concern, install a water trap before the generator. Connect the generator's output directly to sample inlet of the LAS. The nebulizer connects into a rubber stopper in the dilution chamber. The nebulizer has small internal passages for the air jet and the feed tube. These passages can become plugged if the PSL suspension is allowed to dry in the nebulizer. Upon completion of the calibration check, flush out the nebulizer with clean distilled water.

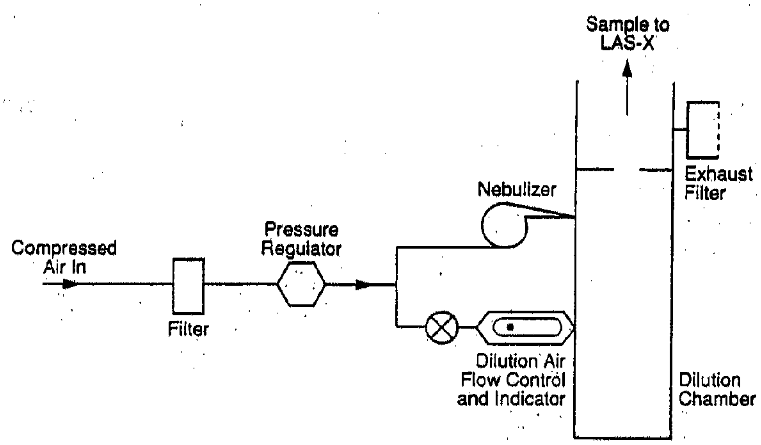

FIG. A1.1 Diagram of PSL Calibration Aerosol Generator

A2. DILUTER CALIBRATION

A2.1 The calibration of a diluter is very similar to that of the filter system penetration measurement. Refer to Fig. A2.1. However, generation of lower particle counts are required for the diluter calibration than for the actual penetration test. It is preferable, but not mandatory, to generate this aerosol in a flow system separate from the system housing of the in-place test to prevent unnecessary loading of the filters. If more than one diluter stage is required, each must be calibrated independently. An example of the diluter calibration plot is indicated in Fig. A2.2, Fig. A2.3. The diluter calibration procedure is as follows:

A2.1.1 Connect the diluter inlet to the flow system with a (HEPA-1) filter cartridge upstream of inlet duct and the diluter, and open Valves C and D. With this arrangement and no aerosol generation, accumulate a background sample with the LAS. Background particle counts are most likely due to leaks in the diluter system and must be eliminated before proceeding.

A2.1.2 Inject test aerosol upstream of the (HEPA-2) filter cartridge and allow a certain portion of the aerosol to bypass the filter by opening Valves A and B. Adjust Valve C to the desired dilution airflow in the diluter with the vacuum pump on. A typical dilution airflow of 250 cm^3/s and a ΔP across the capillary tube of 0.175 kPa are suggested for dilution ratios of 1200 to 1. Open Valve D and allow the LAS to sample the aerosol at the upstream side of the diluter to a level below which causes coincidence counting in the LAS (see 6.1). This sample arrangement establishes the challenge to the diluter. Position Valve D to purge and zero the LAS with filtered air (HEPA-3) before proceeding to the next section.

A2.1.3 Position Valve D to sample the diluted aerosol at the downstream probe of the diluter and calculate the dilution ratio. The equation holds for each specific size particle diameter as:

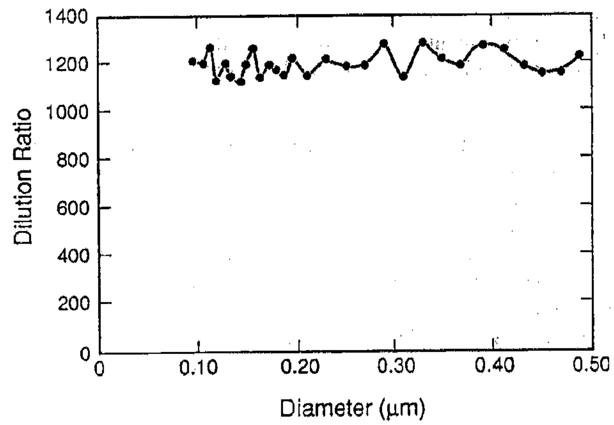

FIG. A2.2 Typical Aerosol Diluter Calibration Plot

$$D = \frac{C_u}{C_d} \quad (A2.1)$$

where:

D = dilution ratio,
C_u = upstream particle counts, and
C_d = downstream, or diluted particle counts.

A2.1.4 Only use the data for the particle size ranges where the dilution ratio remains constant and does not increase by more than 10 % for the overall distribution. Data for particles in sizes above and below that size are not to be used.

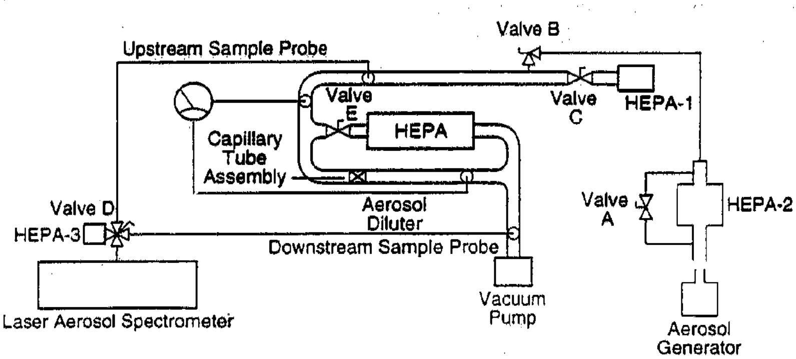

FIG. A2.1 Schematic Diagram of Aerosol Diluter in Calibration Mode

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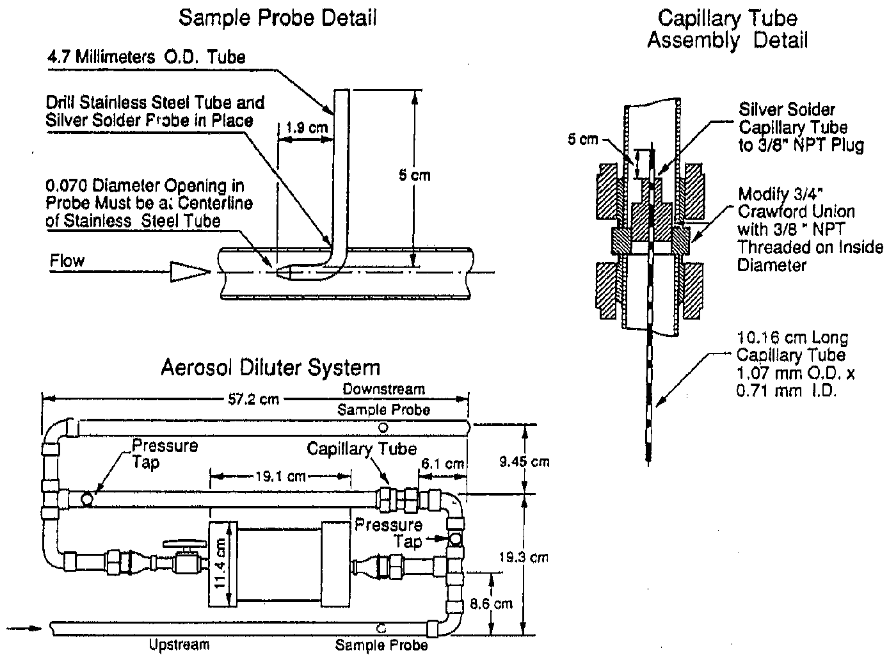

FIG. A2.3 Typical Aerosol Diluter with Dimensions

A3. AIRFLOW DISTRIBUTION AND AIR-TEST AGENT MIXING TESTS

A3.1 *Purpose*—Perform these tests to verify that the system design airflow is consistent with the fan furnished under actual field conditions at minimum and maximum filter pressure drop, and to verify that the airflow distribution across each HEPA filter stage is uniform at the design flow rates.

NOTE A3.1—These tests are to be performed only during acceptance or after extensive modification to the system, except for the airflow capacity and filter pressure drop test, that are required each time the in-place tests are performed.

A3.2 *Acceptance Criteria:*

A3.2.1 *Airflow Capacity Tests*—The system airflow shall be within ±10 % of the value specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be ±10 % of the value specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop.

A3.2.2 *Airflow Distribution Tests*—No velocity readings shall exceed ±20 % of the calculated average. The minimum number of velocity measurements shall be one in the center of each filter. Make all measurements at equal distance away from the filters. It is recommended to conduct these measurements downstream of the filters to take advantage of the airflow distribution dampening effects of HEPA filters.

A3.2.3 *Air-Aerosol Mixing Uniformity Tests*—The purpose of this test is to verify that the challenge aerosol is introduced so as to provide uniform mixing in the airstream approaching the HEPA stage to be tested. When acceptable uniformity is achieved, an upstream sample taken in the same position that the uniformity data were obtained is defined as an acceptable single-point upstream sample. No reading shall exceed± 20 % of the calculated average reading.

APPENDIX

(Nonmandatory Information)

X1. RESULTS OF A ROUND-ROBIN TEST PROGRAM TO EVALUATE A MULTI-STAGE HEPA FILTER SYSTEM USING LASER AEROSOL SPECTROMETER (LAS)

X1.1 *Introduction:*

X1.1.1 The penetration of a two-stage high-efficiency particulate air HEPA filter system was measured by several laboratories using LASs. Single-stage HEPA filters are capable of removing 99.97 % for the particulate matter in air streams for particles having diameters greater than 0.3 μm. The purpose of this filter testing was to evaluate a new test method for determining the performance of two-stage HEPA filter systems. This test method involves challenge of the filters using an oil mist aerosol and subsequent measurements of aerosol penetration using a LAS. The current MIL-STD-282 standard applicable for single-stage filter systems measures the filter penetration at one particle size, approximately 0.3 μm in diameter, using a photometer-type detector. It requires that the challenge aerosol be 0.3 μm in diameter with a geometric standard deviation (σg) of 1.7 for testing. An existing method for in-place testing of HEPA filter systems, using a photometer for penetration measurements, specifies that 50 % of the aerosol be less than 0.7 μm with σg of 1.7. This test method places significant requirements on the test aerosol and yields little information about the dependence of penetration with particle size. The penetration measurements obtained by this test method depend on the challenge aerosol size distribution, the penetration of the filter, and the size response function of the photometer detector **(3)**.

X1.1.2 This test method presented here is an extension of the NE F3-4T **(4)** for in-place testing of HEPA filter systems for the Department of Energy nuclear industry. The main advantages of this test method are increased detection sensitivity, capability to measure the aerosol size distribution, and less required control over the challenge aerosol distribution. The increased sensitivity, achieved by the use of the LAS, allows multi-stage filter systems to be evaluated as a single unit.

X1.1.3 Penetrations as small as 4×10^{-8} can be measured. The typical photometer detector does not have the required sensitivity to measure such low penetrations. Using the LAS, both the challenge and penetrating aerosol size distributions can be measured down to 0.1 μm in diameter. More recent models extend this minimum size to 0.07 μm. With the additional size information, the filter penetration can be calculated either as a function of particle size or in a particular size of interest. This test method can determine the filter penetration of HEPA filters in the particle-size range from 0.1 to 0.2 μm where the greatest penetration is likely to occur. The only requirement on the challenge aerosol is that it lie in the range where the penetration is to be evaluated. Exact specification of its median diameter and standard deviation is not required.

X1.1.4 A major disadvantage to the LAS method is that the detection of aerosols of high concentration is subject to errors due to particle counting coincidence in the LAS. Coincidence errors are avoided by proper dilution of the challenge aerosol prior to sampling.

X1.1.5 This test method can also be used to evaluate the performance of single-stage filter systems. In these cases, lower concentrations of challenge aerosol can be used for testing than in the case of evaluations using the photometer detector.

X1.1.6 In the round-robin tests (RRT) reported here, a two-stage HEPA filter system was challenged with a heterodisperse oil mist aerosol having geometric median diameters ranging from 0.15 to 0.25 μm with a geometric standard deviation of 1.35 to 1.5. The measurements were accomplished with a LAS capable of counting and sizing particles with a 0.1 to 1.0-μm diameter. This test method describes the filtration system, the procedure used to determine penetration, and comparisons of results from the inter-laboratory evaluations.

X1.2 *Experimental Method:*

X1.2.1 The RRT filter system is illustrated in Fig. X1.1. Components included the gas stream flow duct with filters, the aerosol generator, the LAS, aerosol diluter, and pressure loss gages. Major steps associated with penetration measurements included, measuring the background downstream of the second filter stage, and particle-size distribution upstream and downstream of the filters. The test apparatus is designed to evaluate the performance of two standard 60 by 60 by 30-cm HEPA filters in series at 0.47-m^3/s airflow. For the purpose of testing by participating laboratories, upstream and downstream sample probes were each located in a removable 25-cm diameter duct. The upstream sample probe is located approximately eight duct diameters downstream of the aerosol injection position. The downstream sample probe is located eight duct diameters downstream from the second HEPA filter. These distances allow adequate mixing of the aerosol prior to sample extraction.

X1.2.2 The test aerosol was introduced into the duct at approximately eight duct diameters upstream of the sample probe. Aerosol generators used include the Air Techniques Inc., Model No. TDA-5A,[10] as well as modified Air Techniques thermal generators. All laboratories used Di(2-Ethylhexyl) Sebacate (DEHS) to produce the oil mist aerosol. The generators were capable of producing number concentrations in air of 2×10^{6} particles/cm^3(p/cm^3), or about 30 μg/L assuming unit density. High aerosol concentrations must be used so that the aerosol penetrating the dual HEPA system is greater than any background aerosol that may be leaking into the test duct after the second filter. The high concentration also allows the penetration measurements to be made in a reasonable amount

[10] Available from Air Techniques Division of Hamilton Associates, Inc., Baltimore, MD 21207.

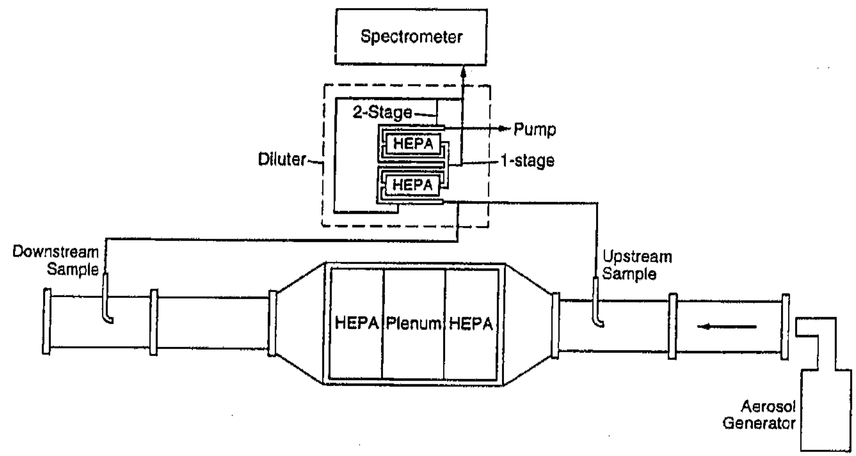

FIG. X1.1 Round-Robin Test Apparatus

of time. For example, with an upstream concentration of 2.5×10^{6} p/cm^3, a filter penetration of 4×10^{-8}, a LAS sample rate of 1.6 cm^3/s, and a downstream sample time of 600 s is required to accumulate 100 particle counts.

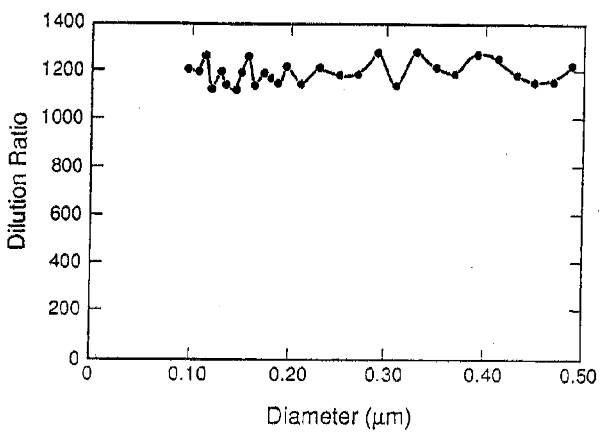

FIG. X1.2 Single-Stage Dilution Ratio, Laboratory 1

X1.2.3 Because of the high aerosol concentration used to challenge the filter system, the upstream aerosol sample must be diluted to prevent particle counting coincidence in the LAS. Particle count rates of greater than 3000 p/s must be avoided to prevent errors due to coincidence. Typically, aerosol dilution ratios of 1000 to 5000 are required. It is desirable that the diluter have minimum particle losses over the size range of interest and that those losses are constant with particle size. Calibration of the diluters can be done with the LAS using a reduced concentration of the same aerosol that is used in testing the filters. The diluter provided with the filter system allowed for either a one- or two-stage dilution. Each stage consisted of a capillary tube that allows a portion of the aerosol to pass while the rest of the air is filtered through a HEPA filter in parallel. A filtered dilution air flow of 250 cm^3/s was provided by an auxiliary pump. Dilutions of about 1000 to 1 can be achieved with a single stage. An example of a diluter calibration plot is shown in Fig. X1.2. The dilution ratio is nearly constant over the size range from 0.1 to 0.5 μm in diameter.

X1.2.4 Most of the testing was performed with the filter test apparatus under a negative pressure, that is with the air blower downstream of the filter unit. Because of this negative pressure, non-test particles can leak into the ducting from outside ambient environment. Since the concentration of test particles penetrating the filters is very low, it is necessary to ascertain the concentration of non-test particles in the system. This non-test or background concentration measurements is performed without aerosol generation and sampling with the LAS from the downstream probe. Sampling is maintained for the same time period as for the downstream aerosol test. It is desirable that the net downstream particle counts (downstream counts less background counts) be at least 100. Also, two successive sample accumulations are recommended and the difference of the two should not exceed 5 % of the larger count.

X1.2.5 The LASs used for the comparisons are capable of counting and sizing test aerosol particles from 0.1 to 1 μm in diameter. This range is adequate to determine the diameter at which maximum penetration occurs through HEPA filters at these flow conditions. The LASs used in the RRT included the Particle Measurement System 64-channel LAS-X model[5] for Laboratories 1 and 3, and a 32-channel ASASP-X for Laboratory 2. The LAS detects aerosol by the amount of scattered light from individual particles and sizes them by pulse height discrimination of the pulses. The LASs calibrated prior to the experiments, used monodisperse aerosol of polystyrene latex spheres (PSL). Minimum detectable sizes were between 0.09 to 0.11 μm in diameter. The LAS's calibrations using PSLs are presented in Fig. X1.3. The smallest sphere used during the calibration were within twice the lowest detectable size of the LAS. The LAS sampling rates ranged from 1.5 to 2 cm^3/s.

X1.2.6 In addition to slight differences in the aerosol generation and particle detection instrumentation used by each laboratory, there were some additional differences in the performance of testing by the laboratories. The dilution system provided with the filter system was inoperable at Laboratory 2 due to damage during shipment. Laboratory 2 testing was

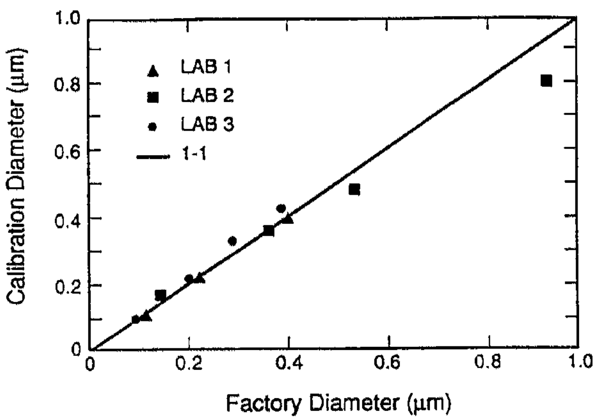

FIG. X1.3 LAS Calibration Using PSLs

accomplished with another two-stage aerosol diluter. The original filters in the system were first evaluated by Laboratories 1 and 2. When the filter system arrived at Laboratory 3, it was determined that the differential pressure across the filters was above the recommended level, therefore requiring filter replacement. The new set of filters were above the recommended change level of 0.14 kPa, therefore requiring filter replacement. The new set of filters in the RRT were tested by Laboratories 1 and 3. Laboratory 1 testing is denoted as "#1" for the first series of tests and "#2" after the filter replacement, respectively. Furthermore, some tests were performed in a pressurized operating mode by Laboratory 2 with the blower placed upstream of the system. The slight positive pressure in the system guaranteed that the penetrating particles are test particles.

X1.2.7 Calculate the penetration of the filter system for each discrete particle diameter. The equation holds for each specific particle diameter as follows:

$$P = \frac{C_d - C_b}{C_u D} \tag{X1.1}$$

and the coefficient of variation as:

$$\frac{\Delta P}{P} = \sqrt{\frac{1}{N_u} + \frac{(C_d + C_b)}{(C_d - C_b)^2} + \left(\frac{\Delta D}{D}\right)^2} \tag{X1.2}$$

where:

C_u = upstream concentration measured by LAS,
C_d = downstream concentration measured by LAS,
C_b = background concentration measured by LAS,
N_u = upstream particle counts,
D = dilution ratio,
ΔD = standard deviation for D, and
ΔP = standard deviation for P.

X1.2.7.1 N_u, ΔP, and ΔD are also functions of particle diameter. Error for the LAS sample volume and filter flow rate is not included in the expression for the coefficient of variation.

X1.3 *Results:*

X1.3.1 Table X1.1 lists a summary of the challenge aerosol characteristics and LAS sampling conditions for each series of tests. Four to seven penetration measurements were performed in each test series. The challenge aerosol count median diameters ranged from 0.15 to 0.25 μm and geometric standard deviation from 1.35 to 1.5. In a few tests the upstream particle concentration was somewhat less than the desired 2×10^6 p/cm^3.

X1.3.2 A comparison between Laboratory 1 and Laboratory 3 penetration results across the two-stage filter system is shown in Fig. X1.4. Penetration results presented are the average of six tests for Laboratory 1 and nine tests for Laboratory 2. The Laboratory 2 results are the average of both positive and negative pressure testing. Very good agreement in penetration values were achieved for diameters greater than 0.2 μm. The maximum penetrations are 3.7×10^{-7} and 3.1×10^{-7} for Laboratory 1 and Laboratory 2, respectively. The diameter at which the maximum penetration occurs is approximately 0.17 μm in both cases. Previous investigators have found the diameter of maximum penetration to be between 0.1 to 0.2 μm for single-stage HEPA filters (**1, 6, 7**). The competing particle capture mechanisms, diffusion, interception and impaction, cause the maximum in the penetration-size relation. The MIL-STD 282 acceptance criteria using the dioctyl phthalate 0.3-μm diameter aerosol with photometer detection is an efficiency of at least 99.97 % for HEPA filter media. The extrapolated penetration for a two-stage filter system, 9×10^{-8}, has been indicated at a diameter of 0.3 μm. It compares favorably with the penetration results from the LAS method.

X1.3.3 In Fig. X1.5 the same data is presented with bounds of ±1 standard deviation for each of the data sets at each particle size. The average penetration of each laboratory essentially lies within these bounds for the other. Differences in penetration are not statistically significant. Standard deviations

TABLE X1.1 Summary of Challenge Aerosol Characteristics and LAS Operation

Participants	Challenge Aerosol		Concentration	Particle counts/s	Dilution Ratio
	CMD (μm)[A]	σg	(10^6 p/cm^3)		
Laboratory 1, Set 1	0.147±0.008	1.45±0.03	2.2 to 4.0	1800 to 3500	1 200
Laboratory 2 Pos[B]	0.213±0.02	1.44±0.02	0.5 to 2.3	300 to 6000	1 000 to 10 000
Laboratory 2 Neg	0.254±0.002	1.46±0.004	2.7 to 4.3	600 to 1500	5 000 to 7 000
Laboratory 3	0.190±0.008	1.50±0.02	0.5 to 4.0	800 to 1300	1 500 to 40 000
Laboratory 1, Set 2	0.164±0.005	1.37±0.04	1.0 to 1.5	600 to 2500	1 000

[A] CMD = count medium diameter as measured by the LAS based on calibrations with PSLs.
[B] This test was conducted with the fan on the upstream side of the RRT filter system.

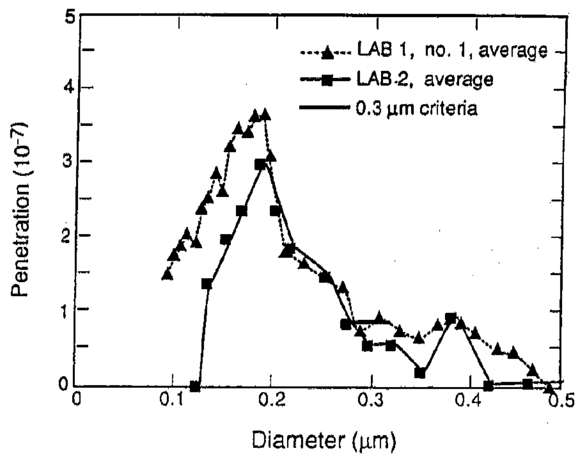

FIG. X1.4 Penetration Results, Laboratories 1 and 2, Two-Stage HEPA Filtration System

reported are about 30 to 60 % at diameter of maximum penetration. These can be explained in large part due to the low particle counts in each of the diameter ranges. Significant error in penetration can also be encountered due to errors in face velocity. An example of the magnitude of this error, as predicted by filtration theory, is presented in Fig. X1.6. At a face velocity of 2 cm/s, a variation of ±5 % in velocity can have associated errors of 30 to 40 % in penetration at the size of maximum penetration. In the current RRT, the method of flow measurements was left up to the participants.

X1.3.4 The comparison of measured penetration with the second set of filters is presented in Fig. X1.7. Higher penetrations were measured by Laboratory 3 for all particle sizes. Only the first test for Laboratory 3 is shown since the pressure drop across the single filter stage increased to 0.75 kPa as the test progressed. The penetration results for Laboratory 1 and 2 are an average of seven tests. The average results do not significantly differ from the Laboratory 3 test results.

X1.3.5 The penetration measurements made under positive and negative operating modes are compared in Fig. X1.9. The average of maximum penetrations are 2.4×10^{-7} and 4.0×10^{-7} for the positive and negative operation, respectively. However, the differences are not significant. Positive operation resulted in near zero background counts with downstream/background count ratios ranging from 30 to 300. Corresponding negative ratios range from 1.2 to 10. Even with considerable amount of background particle accumulation, credible penetration measurements can be made.

X1.3.6 In Fig. X1.8 two sets of average penetration data are compared with the single filtration theory. The theory includes the classical diffusion capture and the interception mechanisms according to Lee and Liu.

X1.4 *Discussion:*

X1.4.1 Using the LAS filter test method, filter systems having penetrations of 10^{-8} to 10^{-5} can be measured. The size of maximum penetration ranged from 0.12 to 0.18 μm in diameter. This is in agreement with both filtration theory and experimental measurements made on single-stage HEPA filter system. Penetration measurements can be achieved in a reasonable length of time and in the presence of aerosol leakage into the system from the external environment.

X1.4.2 The current RRT has indicated that it is feasible to perform penetration measurements on a 0.47-m^3/s rated airflow, two-stage HEPA filter system. It is desirable that future RRT involve a greater number of participants and a common measurement instrumentation. Possible additions to this test method should include specification of the diluter system purge times and a tolerance on the variation in the challenge concentration during testing. The LAS filter test method should continue to be pursued as a viable method for evaluating the performance of HEPA filters in-place having penetrations as low as 10^{-8}.

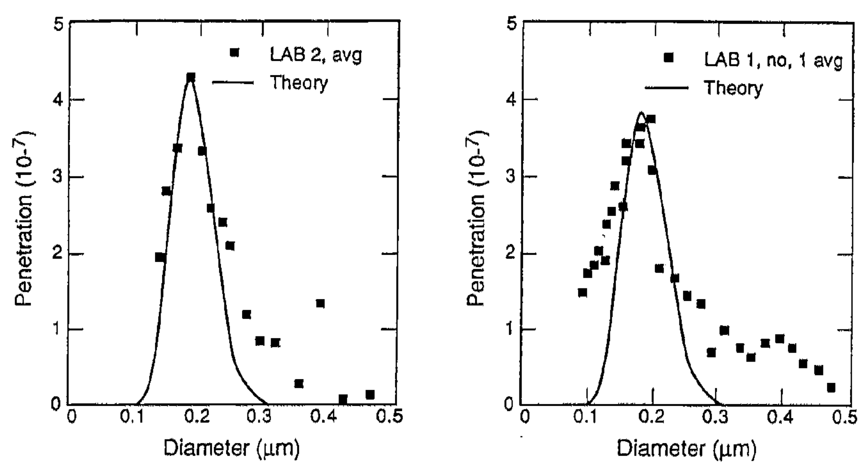

FIG. X1.8 Two Sets of Average Penetration Are Compared With the Single-Filter Filtration Theory

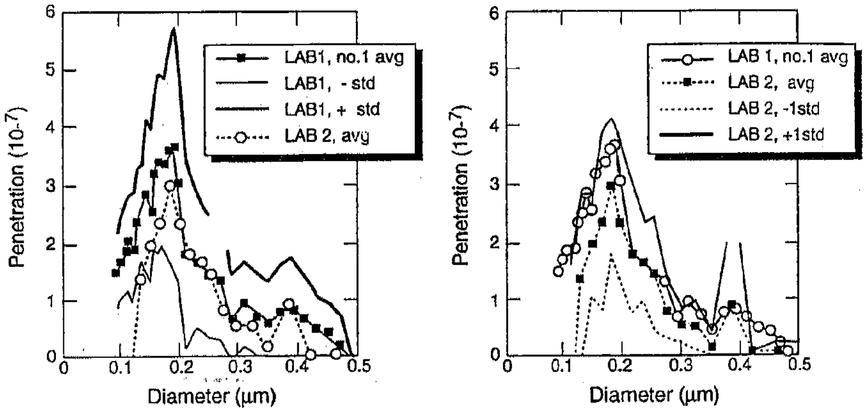

FIG. X1.5 A Plot Showing Average Penetration Measurements for Laboratories 1 and 2 Including Standard Deviation

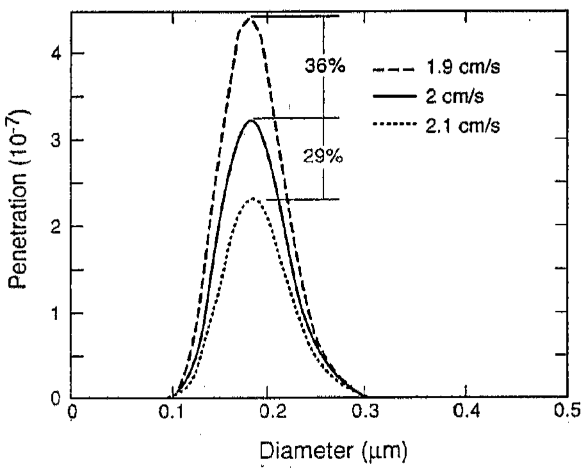

FIG. X1.6 Example of the Magnitude of This Error as Predicated by Filtration Theory

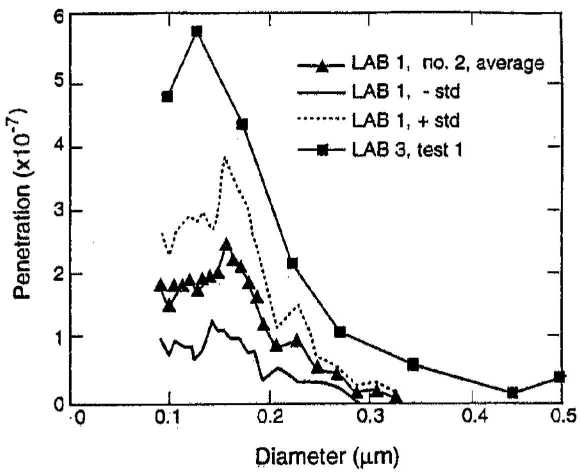

FIG. X1.7 Comparison of Measured Penetration With Second Set of Filters

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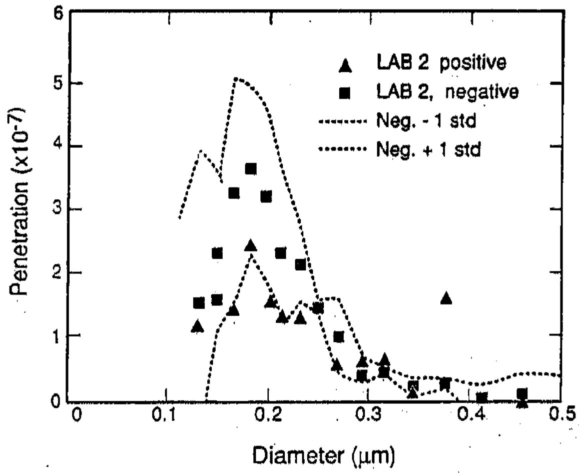

FIG. X1.9 Penetration Measurements Under Positive and Negative Operating Modes

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(1) *Nuclear Air Cleaning Handbook*, ERDA 76-21, National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

(2) *The Coefficient of Variation for Filter Penetration, ASTM STP 975*, ASTM, Philadelphia, PA, October 1986.

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(6) Scripsick, R. C., Smitherman, R. L., and McNabb, S. A.," Operational Evaluation of the High Flow Alternative Filter Test System," *Proceedings of the 19th DOE/NRC Nuclear Air Cleaning Conference*, CONF-860820, May 1987.

(7) da Rosa, R. A., "Particle Size for Greatest Penetration of HEPA Filters and Their True Efficiency," UCRL-53311, Lawrence Livermore National Laboratory, 1982.

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An American National Standard

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for Fire Hose Nozzles[1]

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 Specification for Chromium-Nickel Stainless and Heat-Resisting Steel Spring Wire[2]

A 580/A 580M Specification for Stainless and Heat-Resisting Steel Wire[2]

A 582/A 582M Specification for Free-Machining Stainless and Heat-Resisting Steel Bars[3]

B 117 Practice for Salt Spray (Fog) Testing[4]

D 395 Test Methods for Rubber Property—Compression Set[5]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[5]

D 572 Test Method for Rubber Deterioration by Heat and Oxygen[5]

D 1193 Specification for Reagent Water[6]

2.2 *NFPA Standards:*

NFPA 1963 Standards for Screw Threads and Gaskets for Fire Hose Connections[7]

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.

[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.

Current edition approved Dec. 10, 1996. Published October 1997. Originally published as F 1546 - 94. Last previous edition F 1546 - 94.

[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 03.02.

[5] *Annual Book of ASTM Standards*, Vol 09.01.

[6] *Annual Book of ASTM Standards*, Vol 11.01.

[7] NFPA 1963 may be ordered by contacting the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

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/select 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)[8]

5.1.6 Thread type[9]

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 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 size, shape, 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 Method 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 Pistol grip (optional)

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

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[8] Nozzle material should be galvanically compatible with the intended fire hose couplings.

[9] Threads should conform to a recognized industry standard such as NFPA 1963.

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 4.53 kg. Nozzles for use with 64-mm hoses shall weigh not more than 5.9 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 selection 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 control position. The inability to pass the test ball will be considered 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 dynomometer, 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 dynomometer 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 dynomometer. 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 Test Method B 117, Salt Spray (Fog) Testing, for 120 h.

9.8.3 After completion of the salt spray test, all controls shall operate without sticking or binding. There shall be no evidence of galvanic corrosion between dissimilar metals. For metallic specimens, this test shall be conducted immediately after the tests specified in 9.7.

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 two other 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/m^2 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/m^2 or lower, and no individual heat flux value may be greater than 8.0 kW/m^2.

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

TABLE 1 Sampling for Quality Conformance Testing

Lot Size	Sample Size
2–8	All
9–300	10 %–8 minimum
Over 301	5 %–30 minimum

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CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1548 – 94

An American National Standard

Standard Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings Used in Piping Applications[1]

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 (ε) 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

NOTE 1—See Table 1 for equivalency listing of applicable, equivalent specifications.

2.1 *ASTM Specifications:*

A 47 Specification for Ferritic Maleable Iron Castings[2]

A 48 Specification for Gray Iron Castings[2]

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[3]

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[4]

A 216 Specification for Steel Castings, Carbon Suitable for Fusion for High-Temperature Service[2]

A 234 Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures[3]

A 312 Specification for Seamless and Welded Austenitic Stainless Steel Pipe[3]

A 403 Specification for Wrought Austenitic Stainless Steel Piping Fittings[3]

A 536 Specification for Ductile Iron Castings[2]

A 743 Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant for General Application[2]

B 26 Specification for Aluminum-Alloy Sand Castings[5]

B 75 Specification for Seamless Copper Tube[6]

B 210 Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes[5]

B 369 Specification for Copper-Nickel Alloy Castings[6]

B 584 Specification for Copper-Alloy Sand Castings for General Applications[6]

B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel[7]

F 1476 Specification for the Performance of Gasketed Mechanical Couplings for Use in Piping Applications[8]

2.2 *ANSI Standards:*[9]

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *ANSI/AWWA Standards:*[9]

C151/A21.51 Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water and Other Liquids

C606-87 Grooved and Shouldered Joints

2.4 *Military Standards:*[10]

MIL-A-8625 Anodic Coatings, for Aluminum and Aluminum Alloys

MIL-T-704 Treatment and Painting of Material

MIL-STD-45662 Calibration System Requirements

2.5 *British Standards:*[11]

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 Wrought Aluminum and Aluminum Alloys 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 Chromium—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

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[1] This practice is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee 25.13 on Piping Systems.

Current edition approved August 15, 1994. Published October 1994.

[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.

[5] *Annual Book of ASTM Standards*, Vol 02.02.

[6] *Annual Book of ASTM Standards*, Vol 02.01.

[7] *Annual Book of ASTM Standards*, Vol 02.05.

[8] *Annual Book of ASTM Standards*, Vol 01.07.

[9] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[11] Available from British Standards Institution, 2 Park Street, London W1A 2BS.

TABLE 1 Specification Equivalency Table

Spec. Ref. Number	U.S. Designation ASTM	British Standard	ISO Standard
1	A 47	6681	5922
2	A 48	1452	—
3	A 53	3601	—
4	A 153	729	1459, 1460, 1461
5	A 216	3100	—
6	A 234	1640 Pt. 1	—
7	A 312	3605	—
8	A 403	1640 Pt. 2	—
9	A 536	4772	2531, 4179, 8179
10	A 743	3100	—
11	B 26	1490	3522, 7722
12	B 75	2871	—
13	B 210	1471	290
14	B 369	3071	—
15	B 584	1400	—
16	B 633	1706	2081
	ANSI		
17	B36.10	3600	4200
18	B36.19	3600	4200
	ANSI/AWWA		
19	C151/A21.51	4772	2531, 4179, 8179
20	C606	—	—
	MILITARY STANDARDS		
21	MIL-A-8625	—	—
22	MIL-T-704	—	—
23	MIL-STD-45662	5781	—

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

2.6 *International Standards Organization:*[12]

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 Dip 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. 17, 18, 19 and 12, 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,[13] 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 9 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

[12] Available from ISO Central Secretariat; 1, rue de Varembe; Case postale 56; CH-1211 Geneve 20; Switzerland.

[13] End seal is a registered trademark of the Victaulic Company of America.

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 11. Fabricated fittings shall be made from pipe in accordance with Table 1 Specification Reference 13.

6.2.1 Finish for aluminum alloy fittings shall be bare, anodized in accordance with Table 1 Specification Reference 21, painted in accordance with Table 1 Specification Reference 22 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 10, or Table 1 Specification Reference 8. 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 15. Wrought fittings shall be constructed of copper in accordance with Table 1 Specification Reference 12.

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 14 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. Certification

10.1 *Material Certification:*

10.1.1 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.

11. Inspection

11.1 *Terms of Inspection:*

11.1.1 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.

11.2 *Raw Material Inspection:*

11.2.1 Raw material shall be inspected for compliance with its material specification.

11.3 *Quality Conformance Inspection:*

11.3.1 Fitting samples shall be visually and dimensionally examined to verify compliance with the manufacturer's appropriate drawings.

11.4 *Process Control Inspection:*

11.4.1 Fittings shall be inspected throughout the entire manufacturing and processing cycle. Methods of inspection shall be in compliance with manufacturer's quality assurance procedures.

11.5 *Inspection Records:*

11.5.1 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.

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