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 for Testing[3]

D 883 Terminology Relating to Plastics[3]

D 1141 Practice for the Preparation of Substitute Ocean Water[4]

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

D 1600 Terminology for 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[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 Energy 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

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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 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 04.07.

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

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

2.4 *Other Documents:*

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 *Definitions 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*—Nonconductive 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 1 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, and so forth).

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.

[9] Available from the National Sanitation Foundation, 3475 Plymouth Rd., Ann Arbor, MI 48105.

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

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 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 caused by transportation, handling, installation, personnel traffic, and so forth. 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 h) 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 caused by thermal expansion, contraction, and external loads, such as wind loads, seismic loads, and so forth 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.

7.5.1.1 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, and so forth 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 as a result of 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 in which 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 in which fluid in the system has high flow velocities, abrasive characteristics, or there are flow path discontinuities producing excessive turbulence, the possible effect of erosion shall be considered. If erosion cannot be avoided, then adequate measures shall be taken such as special liners, change of materials, and so forth.

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 $1 \times 10^5 \Omega$/m ($3.281 \times 10^5 \Omega$/ft) 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 $1 \times 10^6\ \Omega$ 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-in. pipe should be cut into three 2- by 18-in. sections, measured along its chord and axially, respectively, (19.5°) to approximate the flat 6- by 18-in. panel required in Test Method E 162. Edges of each of these sections should be cut so that they are completely flush (0.001-in. 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 IMO 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. Measured axially and along its chord (29° segment), 3- by 3-in. 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 is explained in Guide E 800. For purposes of sampling, it may be defined as the point in time up to 2 min 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.

**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 |

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, conductive connections, and test points shall be suitable for the system's intended service and have a lifetime expectation no less than the nonconductive 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, because of 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 before 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 and Use

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.

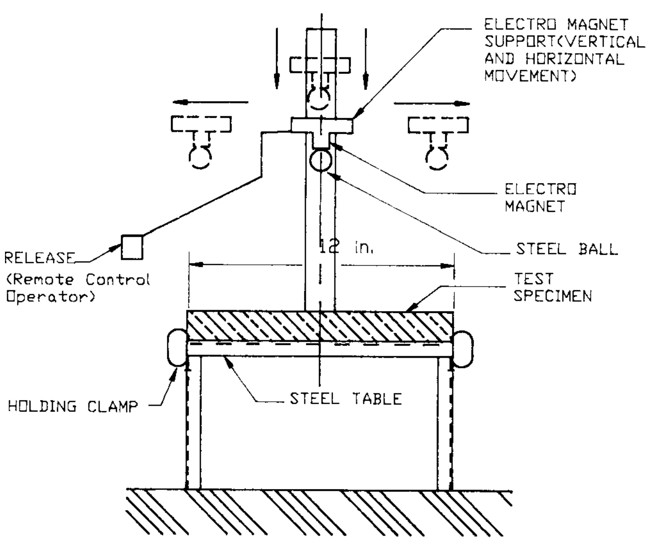



**FIG. A1.1 Test Apparatus**

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 before 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 that 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 before 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 highlight 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 (metres). 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 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 $1 \times 10^5$ Ω/m ($3.281 \times 10^5$ Ω/ft). The procedures in Annex A3 shall be used.

[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.

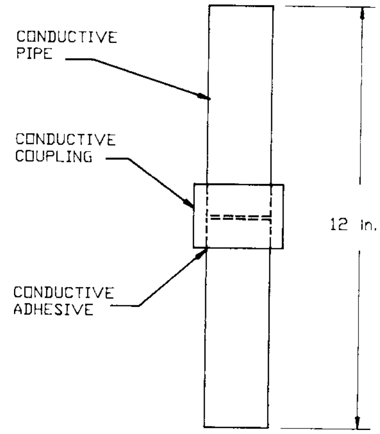



FIG. A2.2 Test Specimens

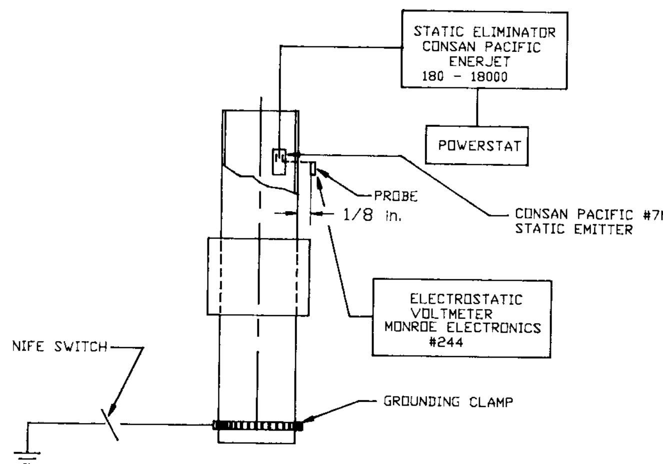



FIG. A2.1 Test Setup

**A2.5 Conditioning**

A2.5.1 No special conditioning of the samples before 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 1 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 characteristics 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*) saltwater per Practice D 1141, (*2*) gasoline, (*3*) Bunker C, and (*4*) 1 % sulfuric acid.

A2.6.8 At the end of one, three, six, and twelve 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-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 one, three, six, and twelve 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 one, three, six, and twelve 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. Fig. 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 $1 \times 10^{10}$ 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]

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

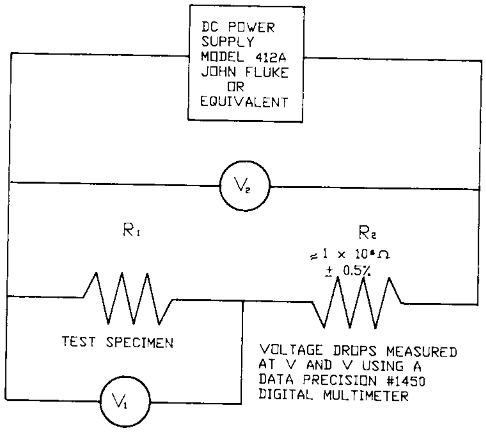



**FIG. A3.1 Test Setup for Determining the Electrical Resistance of Fiberglass Pipe and Fittings**

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* $1 \times 10^6 \pm 0.5\ \% \times 1$ 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, 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 in.

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 A3.7.1.1-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 nonconductive 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 $1500 \pm 0.1$ 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 A3.7.1.4.

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) saltwater per Practice D 1141, (2) gasoline, (3) Bunker C, and (4) 1 % sulfuric acid.

A3.7.9 At the end of one, three, six, and twelve 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-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 one, three, six, and twelve 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 h, simulating a fully developed liquid hydrocarbon fire. This test is valid for pipe 1- 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 nonmetal 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-in. pipe systems. Above 8 in., every third size of the manufacturer's product line shall be tested.

**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 10-min period after the first half hour of the test the area under the curve of mean furnace temperature versus 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.

**TABLE A4.1 Time/Mean Temperature Ramp of Furnace**

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

## 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/(h-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- 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 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).

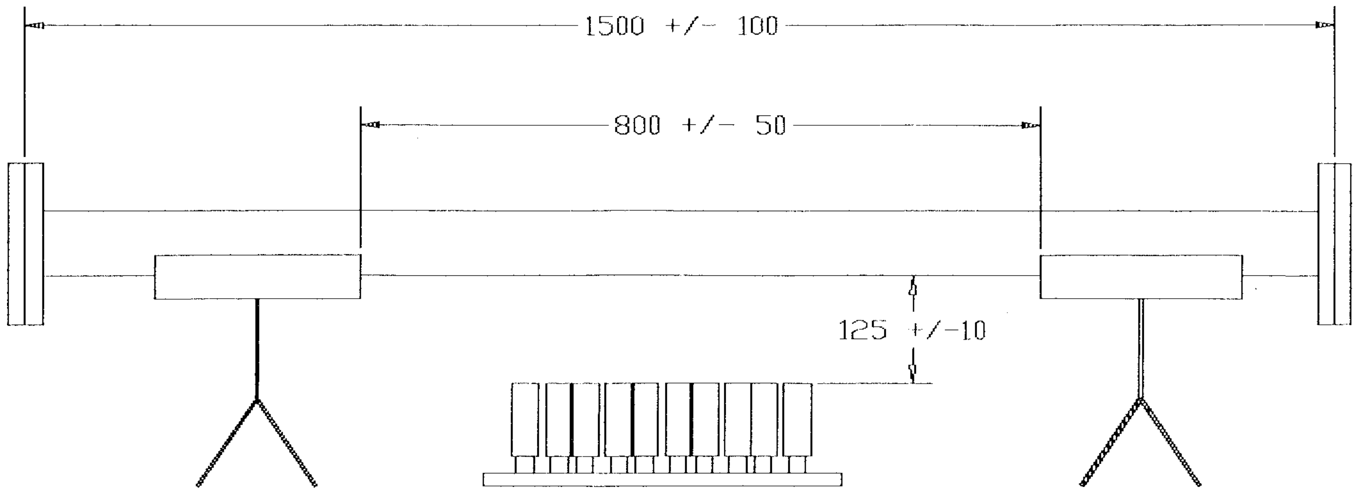



FIG. A5.1 Stand with Mounted Sample

A5.4.2 *Thermocouples*—Two thermocouples capable of 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 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 A5.6.3.

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

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

A5.7.4.2 A constant heat flux averaging 36 011 Btu/(h-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 premix flame of propane with a fuel flow rate of 11.02 lb/h (5 kg/h) for a total heat release of 221 780 btu/h (65 kW).

(*b*) The gas consumption should be measured with an accuracy of at least ±3 % 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-in.

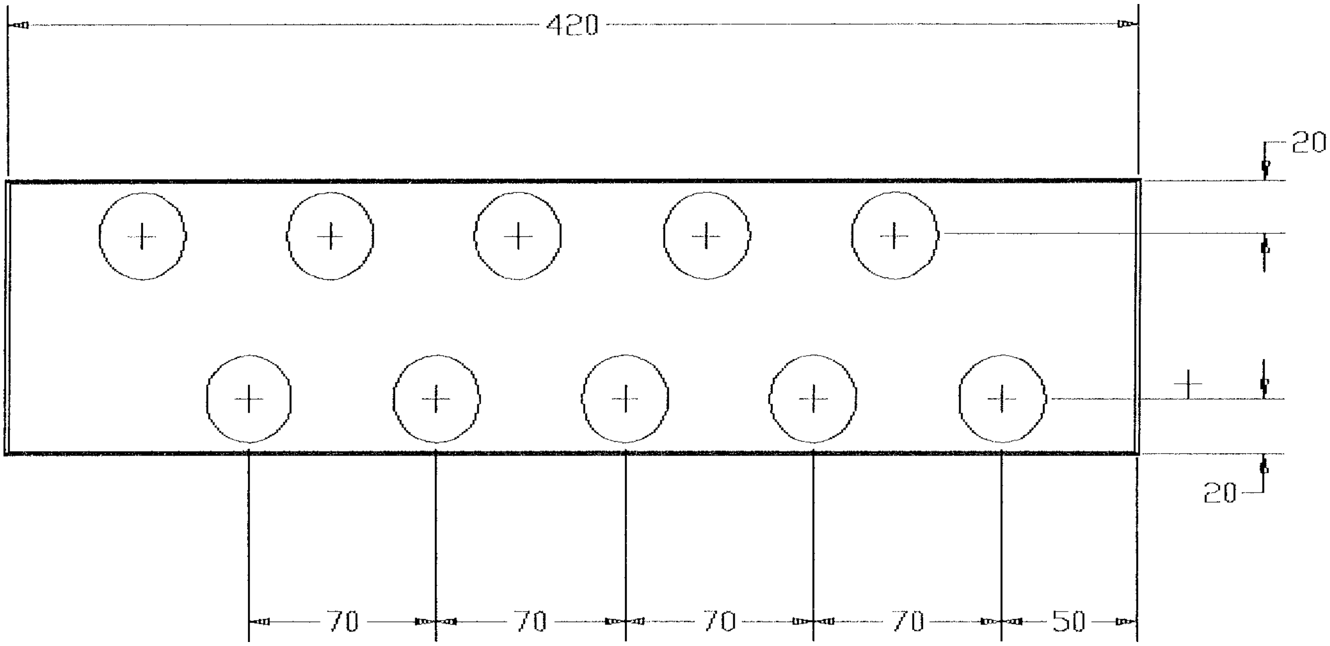



FIG. A5.2 Top View Burner Assembly

increase in pipe diameter.

(*a*) A constant heat flux averaging 36 011 Btu/(h-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 L/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 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

**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 |

**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 |

measured in accordance with 11.4.

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

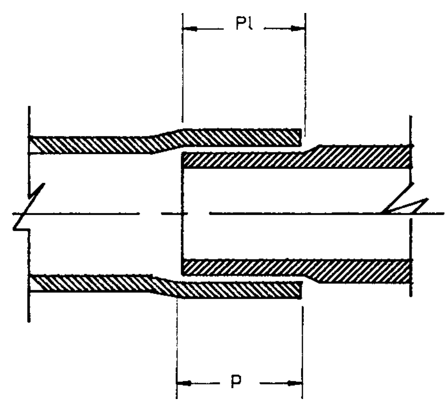
A6.2.3 *Length*—Lengths and tolerances are specified in Figs. A6.1-A6.16.

NOTE A6.1—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 A6.2—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 A6.3—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.

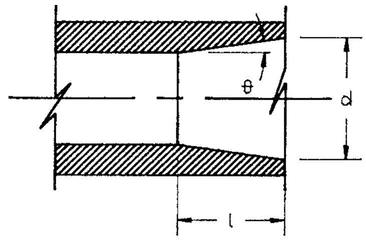
A6.2.4 The lengths and tolerances of fittings not covered in Annex A6 must be agreed upon by the purchaser and the supplier.




| NPS | Minimum Socket Length, P in. (mm) | Minimum Spigot Length, P 1 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**

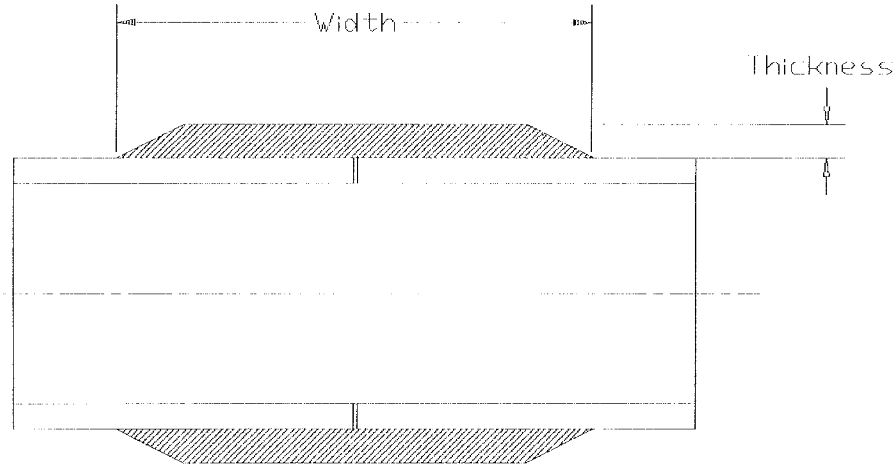



| NPS | Socket Entrance Diameter, min, *d*, in. (mm) | Minimum Effective Bond Length, min, *L*, in. (mm) | Taper Angle Range ° (Degrees) |
|---|---|---|---|
| 1 | 1.335 (34) | 0.750 (19) | 1 to 3 |
| 1½ | 1.910 (76) | 0.750 (19) | 1 to 3 |
| 2 | 2.375 (60) | 1.000 (25) | 1 to 2 |
| 3 | 3.500 (89) | 1.125 (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°, that is, 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).

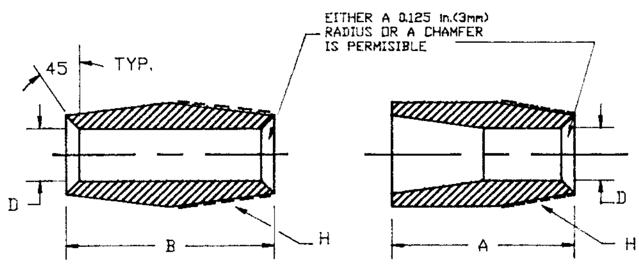
NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

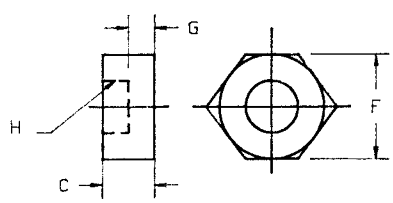
**FIG. A6.2 Standard Taper-to-Taper Joint**




| 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**



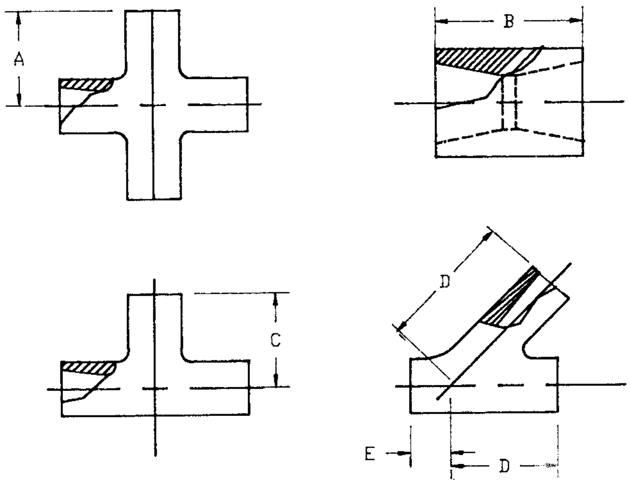

| NPS | Overall Length, min | | | Minimum Internal Diameter D, in. (mm) | Width[A] Across Hex Flats F, in. (mm) | Minimum Thickness G, in. (mm) | Pipe Thread (IPS) H, in. (mm) | Taper Angle Degrees ° |
|---|---|---|---|---|---|---|---|---|
| | A, in. (mm) | B, in. (mm) | C, in. (mm) | | | | | |
| 1 | 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**

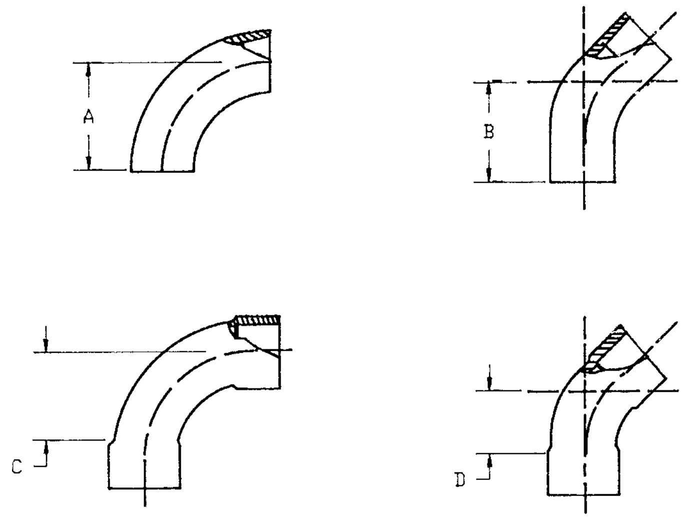



| NPS | A, min, in. (mm) | B, min, in. (mm) | C, min, in. (mm) | D, min, in. (mm) | E, min, in. (mm) |
|---|---|---|---|---|---|
| 1 | 2.500 (64) | 2.500 (64) | 2.500 (64) | 3.625 (92) | 2.250 (57) |
| 1½ | 3.125 (79) | 3.000 (76) | 3.125 (79) | 5.000 (127) | 3.000 (76) |
| 2 | 3.125 (79) | 4.625 (117) | 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**

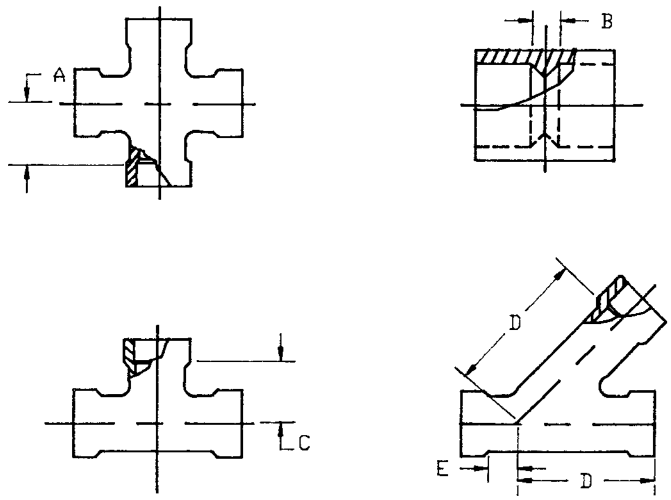



| NPS | A, min, in. (mm)[A] | B, min, in. (mm)[A] | C, min, in. (mm) | D, min, in. (mm) |
|---|---|---|---|---|
| 1 | 2.500 (64) | 2.125 (54) | 2.562 (65) | 0.875 (22) |
| 1½ | 3.125 (79) | 2.625 (67) | 3.188 (81) | 0.125 (29) |
| 2 | 3.125 (79) | 2.375 (60) | 3.000 (76) | 1.375 (35) |
| 3 | 4.375 (111) | 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).

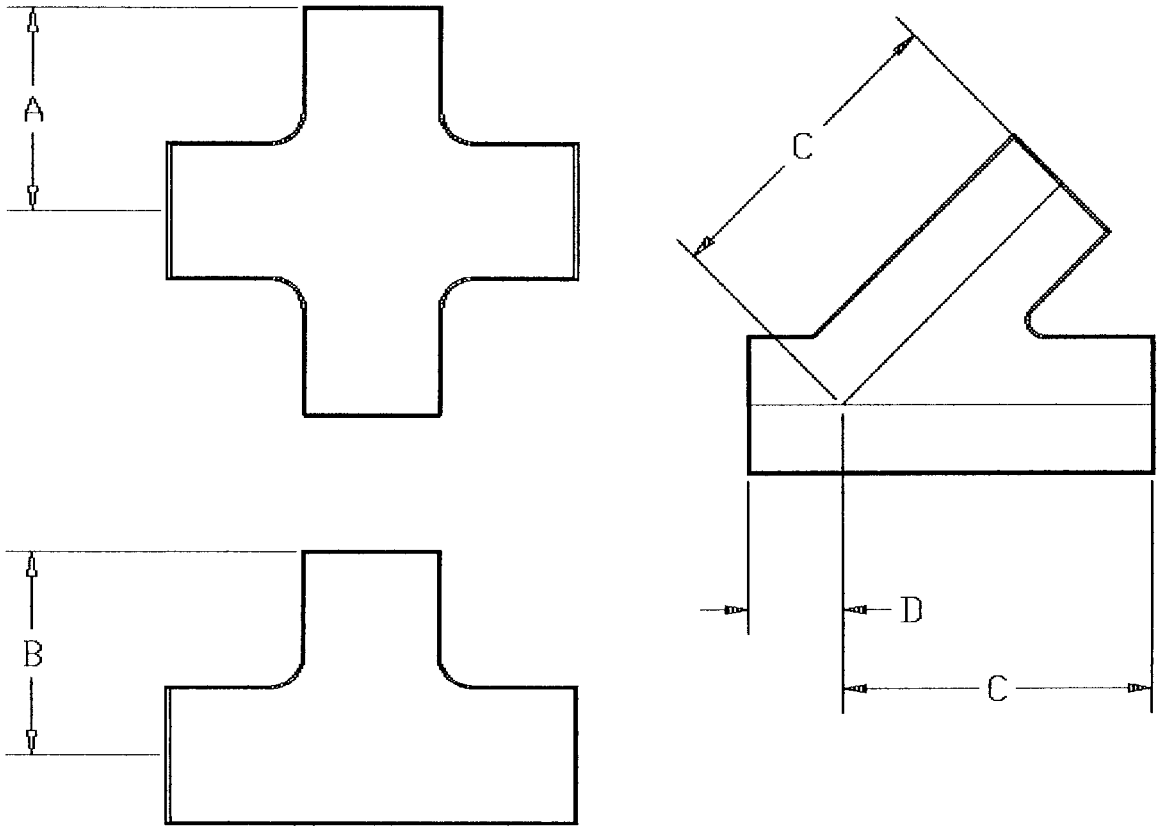
**FIG. A6.6 Taper-to-Taper and Butt-Weld: (A) 90° Elbows and (B) 45° Elbows; Straight-Taper and Straight-to-Straight (C) 90° Elbows and (D) 45° Elbows**




| 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) |

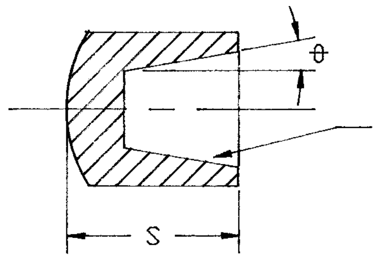
NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

**FIG. A6.7 Straight-Taper and Straight-to-Straight (A) Cross, (B) Coupling, (C) Tee, and (D) and (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 |

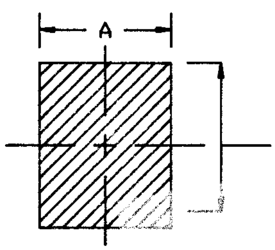
**FIG. A6.8 Plain End (A) Cross, (B) Tee, and (C) and (D) 45° Lateral**




| 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. A6.1.

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

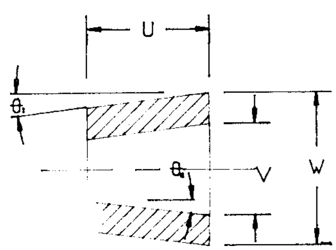

| NPS | A, min, in. (mm)[A] | B, min, in. (mm)[B] |
|---|---|---|
| 1½ by 1 | | 1.250 (32) |
| 2 by 1 | | 2.500 (64) |
| 2 by 1½ | | 1.250 (32) |
| 3 by 1½ | | 3.000 (76) |
| 3 by 2 | | 2.120 (54) |
| 4 by 2 | | 3.000 (76) |
| 4 by 3 | | 2.880 (73) |
| 6 by 3 | | 3.810 (94) |
| 6 by 4 | | 3.690 (94) |
| 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]Throughout, A = 2.5° (outside diameter – inside diameter).
[B]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).

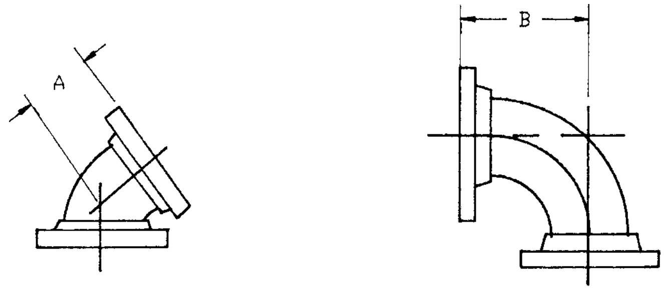
**FIG. A6.11 Taper Body Reducer: (A) Taper by Taper and Plain End and (B) Straight Taper and Straight by Straight**




| 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) |

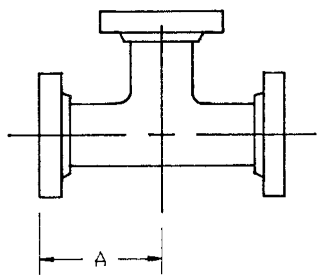
NOTE 1—For tapered socket dimensions, see Fig. A6.2 and Note 1, Fig. A6.2. For external taper, see Note 1, Fig. A6.2 (reference spigot design).

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



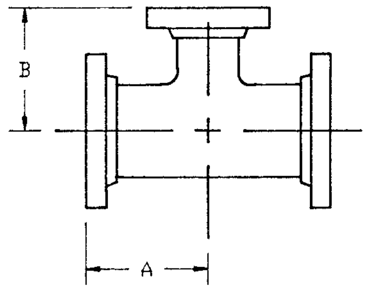

| NPS | A, min, in. (mm) | B, min, in. (mm) |
|---|---|---|
| 18 | 17.250 (438) | 27.000 (432) |
| 20 | 19.000 (483) | 30.000 (762) |
| 22 | 20.875 (530) | 33.750 (857) |
| 24 | 22.750 (578) | 36.000 (914) |
| 26 | 24.500 (622) | 39.750 (1010) |
| 28 | 26.375 (670) | 42.750 (1086) |
| 30 | 26.500 (673) | 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° Flanged Elbow and (B) 90° Flanged Elbow**



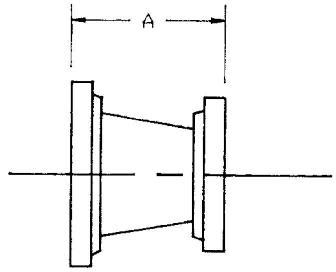

| NPS | Center to Contact Surface "A," min, in. (mm) |
|---|---|
| 18 | 22.500 (572) |
| 20 | 24.750 (629) |
| 22 | 27.000 (686) |
| 24 | 29.250 (743) |
| 26 | 31.500 (800) |
| 28 | 33.750 (857) |
| 30 | 35.500 (902) |
| 32 | 38.250 (972) |
| 34 | 40.500 (1029) |
| 36 | 40.500 (1029) |

**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**

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