



Standard Specification for Thermosetting Resin Fiberglass Pipe Systems to Be Used for Marine Applications¹

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1. Scope

1.1 This specification covers reinforced thermosetting resin pipe systems with nominal pipe sizes (NPS) 1 through 48 in. (25 through 1200 mm) which are to be used for all fluids approved by the authority having jurisdiction in marine piping systems.

1.2 The dimensionless designator NPS has been substituted for traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.3 Values stated in inch-pound are to be regarded as the standard. Values given in parentheses are for information only.

1.4 The following safety hazards caveat pertains to the test methods which are included in this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- D883 Terminology Relating to Plastics
- D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
- D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
- D2105 Test Method for Longitudinal Tensile Properties of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
- D2310 Classification for Machine-Made “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe

- D2584 Test Method for Ignition Loss of Cured Reinforced Resins
- D2924 Test Method for External Pressure Resistance of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
- D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
- D3567 Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
- D5028 Test Method for Curing Properties of Pultrusion Resins by Thermal Analysis
- D5686 Specification for “Fiberglass”(Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Pipe Fittings, Adhesive Bonded Joint Type Epoxy Resin, for Condensate Return Lines (Withdrawn 2002)³
- E1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies
- F412 Terminology Relating to Plastic Piping Systems

2.2 Other Documents:

- ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings⁴
- ANSI B16.5 Pipe Flanges and Flanged Fittings⁴
- IMO Resolution A.753(18) Guidelines for the Application of Plastic Pipes on Ships⁵
- NSF-61⁶
- Code of Federal Regulations 21CFR175.105, 21CFR177.2280, 21CFR177.2410, and 21CFR177.2420⁵
- Code of Federal Regulations Title 46, Part 56, for Piping Systems, and Subpart 56.60-25 for Nonmetallic Materials⁵
- IMO Resolution A.653(16) Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials⁵

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

³ The last approved version of this historical standard is referenced on www.astm.org.

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

⁵ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.

⁶ Available from the National Sanitation Foundation, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140.

IMO Resolution MSC.61(67) International Code for Application of Fire Test Procedures⁵

OTI 95 634 Jet-Fire Resistance Test of Passive Fire Protection Materials⁷

2.3 ISO Documents:

ISO 9001 Quality Management Systems—Requirements⁴

ISO 75 Plastics—Determination of Temperature of Deflection Under Load⁴

3. Terminology

3.1 Definitions are in accordance with Terminologies D883 and F412.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *continuously electrically conductive, adv*—pipe and fittings made conductive using discretely conductive materials or layers.

3.2.2 *homogeneously electrically conductive, adv*—pipe and fittings made conductive using a resin additive so that conductivity is maintained between any two points on the pipe or fitting.

3.2.2.1 *Discussion*—For conveying nonconducting fluids (those having conductance less than 1000 pico-Siemens per metre), pipe systems which are continuously or homogeneously conductive or have conductivity from the inside surface to the outside surface are recommended. In accordance with IMO Resolution A.753(18), all pipe located in a hazardous area, regardless of the fluid being conveyed, must be electrically conductive.

3.2.3 *maximum operating pressure, n*—the highest pressure that can exist in a system or subsystem under normal operating conditions.

3.2.4 *representative piping system, n*—a system composed of a single manufacturer's pipes, fittings, joints, and adhesives that would normally be used by a customer or installer.

4. Classification

4.1 *General*—Pipe and fittings are to be classified using the following system which is similar to that of Classification D2310 for pipe.

4.1.1 *Types:*

4.1.1.1 *Type I*—Filament wound.

4.1.1.2 *Type II*—Centrifugally cast.

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

4.1.2 *Resin:*

4.1.2.1 *Resin 1*—Epoxy resin.

4.1.2.2 *Resin 2*—Vinylester resin.

4.1.2.3 *Resin 3*—Polyester resin.

4.1.2.4 *Resin 4*—Phenolic resin.

4.1.2.5 *Resin 5*—Customer-specified resin.

4.1.3 *Class:*

4.1.3.1 *Class A*—No liner.

4.1.3.2 *Class B*—Reinforced liner.

4.1.3.3 *Class C*—Nonreinforced liner.

4.2 *Pressure Rating*—Pipe and fittings shall be classified as to the method used to obtain their pressure rating (refer to Appendix X1).

4.2.1 *Rating Method 1*—Short-term test.

4.2.2 *Rating Method 2*—Medium-term (1000-h) test.

4.2.3 *Rating Method 3*—Long-term (10 000-h) test.

4.2.4 *Rating Method 4*—Long-term (10 000-h) regression test.

4.3 *Fire Endurance*—Piping systems are to be classified in accordance with the following cells if fire performance is to be specified (refer to Appendix X2).

4.3.1 *Fluid:*

4.3.1.1 *Fluid E*—Empty.

4.3.1.2 *Fluid EF*—Initially empty for 5 min, followed by flowing water. Fluid velocity of 3-ft/s maximum during qualification test.)

4.3.1.3 *Fluid S*—Stagnant water.

4.3.2 *Fire Type:*

4.3.2.1 *Fire Type JF*—Jet fire with heat flux between 95 100 and 126 800 Btu/(h-ft²) (300 and 400 kW/m²).

4.3.2.2 *Fire Type IF*—Impinging flame with heat flux of 36 011 Btu/(h-ft²) (113.6 kW/m²).

4.3.2.3 *Fire Type HF*—Hydrocarbon furnace test at 2012°F (1100°C).

4.3.3 *Integrity/Duration:*

4.3.3.1 *Integrity A*—No leakage during or after fire test.

4.3.3.2 *Integrity B*—No leakage during fire test, except a slight weeping is acceptable. Capable of maintaining rated pressure for a minimum of 15 min with a leakage rate of 0.05 gal/min (0.2 L/min) after cooling.

4.3.3.3 *Integrity C*—Minimal or no leakage (0.13 gal/min (0.5 L/min)) during fire test. Capable of maintaining rated pressure with a customer-specified leakage rate after cooling.

4.3.3.4 *Duration*—The duration of the test shall be specified in minutes and shall be specified or approved by the authority having jurisdiction.

5. Ordering Information

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

5.1.1 *Service Conditions:*

5.1.1.1 Fluid being transported.

5.1.1.2 Design temperature (reference 6.6).

5.1.1.3 Internal design pressure.

5.1.1.4 External design pressure.

5.1.2 *General Information:*

5.1.2.1 Type (reference 4.1.1).

5.1.2.2 Resin (reference 4.1.2).

5.1.2.3 Class (reference 4.1.3).

5.1.3 *Pressure Rating Method (Internal Only)* (reference 4.2).

5.1.4 *Fire Endurance:*

5.1.4.1 Fluid (reference 4.3.1).

5.1.4.2 Fire type (reference 4.3.2).

5.1.4.3 Integrity (reference 4.3.3).

5.1.4.4 Flame spread rating (reference 6.4).

5.1.4.5 Smoke and other toxic products of combustion (reference 6.5).

⁷ Offshore Technology Information (OTI) Report is available from Health and Safety Executive, HSE Information Centre, Broad Ln., Sheffield, S3 7HQ, U.K.

5.1.5 NPS.

5.1.6 Manufacturer's Identification (part number, product name, and so forth).

5.1.7 Specific job requirements (that is, potable water usage, electrical conductivity).

6. Performance Requirements

6.1 *Internal Pressure*—All components included in the piping system shall have pressure ratings suitable for the intended service. Pressure ratings shall be determined in accordance with [Appendix X1](#) using the method specified by the customer or a longer-term method, if available. If, for example, a Rating Method 2—medium-term test is specified and data for Rating Method 3—long-term test is available, then the long-term test data is acceptable. Note that for some components, particularly specialty fittings, long-term testing is not practical and ratings for these items will typically be determined using Rating Test Method 1.

6.2 *External Pressure*—All pipe included in the piping system shall have external pressure ratings suitable for the intended service. External pressure ratings shall be determined by dividing the results of Test Method [D2924](#) by a minimum safety factor of 3.

6.3 *Fire Endurance*—The piping system shall have the fire endurance required by the authority having jurisdiction based on the intended location and service. Fire endurance shall be determined using the appropriate method in [Appendix X2](#).

6.4 *Flame Spread*—The authority having jurisdiction shall designate any flame spread requirements based on the location of the piping. For ships, mobile offshore drilling units (MODU's), and floating oil production platforms subject to the requirements of SOLAS or Title 46 of the U.S. Code of Federal Regulations, performance shall be determined by test procedures given in IMO Resolution MSC.61(67), Annex 1, Part 5—Test for Surface Flammability, as modified for pipes in Appendix 3 of IMO Resolution A.753(18).

6.5 *Smoke and Other Toxic Products of Combustion*—The authority having jurisdiction shall designate any smoke and toxicity requirements based on the location of the piping. For ships, MODUs, and floating oil production platforms subject to the requirements of SOLAS or Title 46 of the U.S. Code of Federal Regulations, performance shall be determined by test procedures given in IMO Resolution MSC.61(67), Annex 1, Part 2—Smoke and Toxicity Test, as modified in B.9.0 of Appendix B—Fire Performance Tests.

6.6 *Temperature*—The maximum working temperature shall be at least 36°F (20°C) less than the minimum glass transition temperature (determined in accordance with Test Method [D5028](#) or equivalent) or heat distortion temperature (determined in accordance with ISO 75 Method A, or equivalent) of the resin or plastic material. The minimum glass transition temperature or heat distortion temperature, whichever is less, shall not be less than 176°F (80°C).

NOTE 1—Glass transition temperature shall be used for in-process quality control testing (reference [9.1.4](#), [9.2.4](#), and [9.3.3](#)).

6.7 *Material Compatibility*—The piping material shall be chemically compatible with the fluid being carried and any fluid in which it will be immersed.

6.8 *Electrical Resistance*—Conductive piping systems shall have a resistance per unit length not to exceed $3.05 \times 10^4 \Omega/\text{ft}$ ($1 \times 10^5 \Omega/\text{m}$) when tested in accordance with [Appendix X3](#). Resistance to earth at any location on an installed piping system required to be conductive shall be no greater than $1 \times 10^6 \Omega$.

6.9 *Static Charge Shielding*—Conductive piping systems shall have a maximum resulting voltage not to exceed 1 % of the supply voltage induced on the exterior surface of the pipe when tested in accordance with [Appendix X3](#).

6.10 *Potable Water Usage*—The material, including pipe, fittings, adhesive, and any elastomeric gaskets required shall have no adverse effect on the health of personnel when used for potable water service. Material shall conform to National Sanitation Standard 61 or meet the requirements of FDA Regulations 21 CFR 175.105 and 21 CFR 177.2280, 21 CFR 177.2410, or 21 CFR 177.2420.

7. Other Requirements

7.1 *Flanges*—Standard flanges shall have bolt patterns in accordance with ANSI B16.5 Class 150 for nominal pipe sizes 24-in. and smaller and in accordance with ANSI B16.1 Class 125 for larger flanges. Consult the manufacturer's literature for bolt length, torque specifications, and tightening sequence.

7.2 *Military Usage*—Piping and fittings used in military applications shall comply with the provisions of Appendix D, Supplementary Requirements to Specification F1173 for U.S. Navy use.

8. Workmanship and Appearance

8.1 All pipe, fittings, and spools shall be visually inspected for compliance with the requirements stated in [Table 1](#), and, if appropriate, either repaired or rejected. After all minor repairs, a pressure test in accordance with [9.1.1](#), [9.2.1](#), or [9.3.1](#) shall be performed on the component.

9. Inspection and Sampling

9.1 Pipe:

9.1.1 *Pressure Tests*—A minimum of 5 % of pipe joints shall be tested at a pressure of not less than 1.5 times the pipe system pressure rating.

9.1.2 *Lot Size*—A lot of pipe shall consist of 150 joints, or fractions thereof, of one size, wall thickness, and grade in continuous production.

9.1.3 *Short-Term Burst Tests*—Short-term hydrostatic burst tests shall be conducted in accordance with Test Method [D1599](#) at a minimum frequency of one test per lot. If the measured value is less than 85 % of the published value, the lot is rejected or subject to retest.

9.1.4 *Degree of Cure*—The glass transition temperature (T_g) shall be determined at a minimum frequency of one test per production lot. If the measured value is more than 10°F less than the value in the manufacturer's specification, the lot is rejected or subject to retest.

TABLE 1 Visual Acceptance Criteria

| Defect Type | Description | Acceptance Criteria | Corrective Action |
|---------------|---|---|----------------------------------|
| Burn | thermal decomposition indicated by distortion or discoloration of the laminate surface | none permitted | reject |
| Chip | small piece broken from edge or surface—if reinforcement fibers are broken, the damage is considered a crack | if there are undamaged fibers exposed over any area; or no fibers are exposed but an area greater than 0.4 by 0.4 in. (10 by 10 mm) lacks resin if no fibers are exposed, and the area lacking resin is less than 0.4 by 0.4 in. (10 by 10 mm) | minor repair accept |
| Crack | actual separation of the laminate which is visible on opposite surfaces and often extends through the wall; reinforcement fibers are often visible/broken | none permitted | reject |
| Crazing | fine hairline cracks at or under the surface of the laminate; white areas are not visible | crack lengths greater than 1.0 in (25.4 mm) crack lengths less than 1.0 in (25.4 mm) | minor repair accept reject |
| Dry spot | area of incomplete surface film where the reinforcement has not been wetted by resin | none permitted | reject |
| Fracture | rupture of the laminate with complete penetration; majority of fibers broken; visible as lighter colored area of interlaminar separation | none permitted | reject |
| Inclusion | foreign matter wound into the laminate | none permitted in structural wall (treat same as pit if located at the surface) | reject |
| Pit (pinhole) | small crater in the surface of the laminate; width is on the same order of magnitude as the depth | diameter greater than 0.032 in. (0.8 mm) or depth greater than 10 % of wall thickness, or both diameter less than 0.032 in. (0.8 mm) and depth less than 10 % of wall thickness | minor repair accept |
| Restriction | excessive resin, adhesive, or foreign matter on the internal wall of pipe/fittings | none permitted | remove by careful grinding |
| Wear scratch | shallow mark caused by improper handling, storage, or transportation, or combination thereof—if reinforcement fibers are broken, the damage is considered to be a crack | undamaged fibers exposed over any area or no fibers are exposed but an area greater than 0.4 by 0.4 in (10 by 10 mm) lacks resin no fibers exposed and the area lacking resin is less than 0.4 by 0.4 in. (10 by 10 mm) | minor repair accept |

9.1.5 *Glass Content*—The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with Test Method **D2584**. If the measured glass content is not within 5 % of the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.1.6 *Wall Thickness*—Total wall thickness and reinforced wall thickness shall be determined in accordance with Practice **D3567** once per every production lot. Total and reinforced wall thickness shall be as specified in **Table 2**. Any out of tolerance components shall be rejected and the remainder of the lot be subject to retest.

9.2 Fittings:

TABLE 2 Wall Thickness Tolerances

NOTE 1—Where measurement of the reinforced wall thickness would cause destruction or damage to the part, only the total wall thickness measurement need be taken.

| Dimension | Tolerance, % |
|---------------------------|--------------------------|
| Total wall thickness | +22.5 ^A –0 |
| Reinforced wall thickness | +22.5 ^A –0 |

^A The tolerance on total and reinforced wall thickness for fittings shall refer to the manufacturer’s designated location on the body of the fitting.

9.2.1 *Pressure Tests*—A minimum of 5 % of each fitting lot shall be tested at a pressure of not less than 1.5 times the pipe system pressure rating. All samples shall hold the test pressure for a minimum of 2 min.

9.2.2 *Lot Size*—A lot shall consist of 50 fittings or one day’s production of a specific fitting, whichever is greater. By agreement between the manufacturer, the purchaser, and the authority having jurisdiction, the lot size shall be permitted to be altered.

9.2.3 *Short-Term Burst Tests*—Short-term hydrostatic burst tests shall be conducted in accordance with Test Method **D1599** at a minimum frequency of one test per lot. If the measured value is less than 85 % of the published value, the lot is rejected or subject to retest.

9.2.4 *Degree of Cure*—The *T_g* shall be determined at a minimum frequency of one test per production lot. If the measured value is more than 10°F less than the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.2.5 *Glass Content*—The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with Test Method **D2584**. If the measured glass content is not within 5 % of the value in the manufacturer’s specification, the lot is rejected or subject to retest.

9.2.6 *Wall Thickness*—Total wall thickness and reinforced wall thickness shall be determined in accordance with Practice **D3567** once per every production lot. Total and reinforced wall thickness shall be as specified in **Table 2**. Any out of tolerance components shall be rejected.

9.3 *Flanges and Mitered Fittings* :

9.3.1 *Pressure Tests*—One mitered fitting from each lot shall be tested to a pressure equal to or greater than 1.5 times the pipe system rating. All samples shall hold the pressure for a minimum of 2 min.

9.3.2 *Lot Size*—A lot shall consist of 20 flanges or 10 mitered fittings of any given configuration.

9.3.3 *Degree of Cure*—The T_g shall be determined at a minimum frequency of one test per production lot. If the measured value is more than 10°F less than the value in the manufacturer's specification, the lot is rejected or subject to retest.

9.3.4 *Glass Content*—The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with Test Method **D2584**. If the measured glass content is not within 5 % of the value in the manufacturer's specification, the lot is rejected or subject to retest.

9.3.5 *Wall Thickness*—Total wall thickness and reinforced wall thickness shall be determined in accordance with Practice **D3567** once per every production lot. Total and reinforced wall thickness shall be as specified in **Table 2**. Any out-of-tolerance components shall be rejected and the remainder of the lot be subject to retest.

9.4 *Retest*—If any test result in **9.1**, **9.2**, or **9.3**, or combination thereof, fails to conform to the specified requirements,

the manufacturer shall be permitted to elect to reject the entire lot, or retest two additional samples from the same lot. If both of the retest specimens conform to the requirements, all items in the lot shall be accepted except the sample which initially failed. If one or both of the retest samples fail to conform to the specified requirements, the manufacturer shall reject the entire lot or test individually the remaining samples in the lot in accordance with **9.1.1**, **9.2.1**, or **9.3.1**, as applicable. Note that in the final case, all samples need only be subjected to the tests that the original samples failed.

9.5 *Production Quality Documentation*—The manufacturer shall have manufacturing procedures for each component to be supplied, raw material test certificates for each component to be used in manufacturing, and production quality control reports available for the procurement officer.

10. Certification

10.1 The pipe manufacturer shall be registered by an accredited agency to meet the requirements of ISO 9001. For purposes of this specification, the manufacture shall be considered a "special process" as defined in ISO 9001, Section 4.9.

11. Product Marking

11.1 Pipe and fittings shall be marked with the name, brand, or trademark of the manufacturer; NPS; manufacture date; pressure rating; pressure rating method; and other information upon agreement between the manufacturer and the purchaser.

12. Keywords

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

APPENDIXES

(Nonmandatory Information)

X1. DETERMINATION OF INTERNAL PRESSURE RATING FOR PIPE, FITTINGS, AND JOINTS

X1.1 Internal pressure rating for a piping system shall be determined using one of four methods. The method used to determine this rating shall be clearly identified by the manufacturer in published literature.

X1.1.1 *Rating Method 1—Short-Term Test Method*—Two samples of each pipe, joint, fitting, or other component shall be tested in accordance with Test Method **D1599** at ambient temperature. The maximum rating for mitered (hand lay-up) fittings shall be determined by dividing the lesser result by a safety factor of 5.0. The maximum rating for all other components shall be determined by dividing the lesser result by a safety factor of 4.0.

X1.1.2 *Rating Method 2—Medium-Term (1000-h) Test*—Two samples of each pipe, joint, fitting, or other component are to be tested in accordance with Test Method **D1598** for a period of 1000 h at the rated temperature. Both specimens must survive the exposure period without leakage. The maximum rating for mitered (hand lay-up) fittings shall be determined by

dividing the test pressure by a safety factor of 2.5. The maximum rating for all other components shall be determined by dividing the test pressure by a safety factor of 2.2.

X1.1.3 *Rating Method 3—Long-Term (10 000-h) Test*—Two samples of each pipe, joint, fitting or other component are to be tested in accordance with Test Method **D1598** for a period of 10 000 h at the rated temperature. Both specimens must survive the exposure period without leakage. The maximum rating for mitered (hand lay-up) fittings shall be determined by dividing the test pressure by a safety factor of 2.0. The maximum rating for all other components shall be determined by dividing the test pressure by a safety factor of 1.87.

X1.1.4 *Rating Method 4—Long-Term (10 000-h) Regression Test*—Pipe, fittings, and joints shall be tested in accordance with Practice **D2992** Procedure B at the rated temperature. The pressure rating for all components shall be determined in accordance with the hydrostatic design basis (HDB) and lower confidence limit (LCL) as calculated in the

test method. Ratings shall be determined by dividing the LCL at 20 years by a factor of 1.5. Scaling of the results is allowed for pipe bodies only in accordance with the ISO equation:

$$S \times SF = P(D - t_r)/2t_r \quad (X1.1)$$

where:

S = hoop stress, psi (kPa),
 SF = service factor,

D = mean reinforced diameter (OD – t) or (ID + t), in. (mm),
 P = internal pressure psig (kPa), and
 t_r = minimum reinforced wall thickness, in. (mm).

NOTE X1.1—Liner thickness is not to be used in determining inside diameter.

NOTE X1.2—Coating thickness is not to be used in determining outside diameter.

X2. FIRE PERFORMANCE TESTS

X2.1 Fire performance tests shall be performed at an independent third-party laboratory to the satisfaction of the authority having jurisdiction.

X2.2 Piping Material Systems:

X2.2.1 All fire endurance, flame spread, and smoke and toxicity testing, where required, shall be conducted on each piping material system.

X2.2.2 Changes in either the type, amount, or architecture, or combination thereof, of either the reinforcement materials, resin matrix, liners, coatings, or manufacturing processes shall require separate testing in accordance with the requirements of this specification.

X2.3 Fire-Protective Coatings:

X2.3.1 Where a fire-protective coating is necessary for achieving the fire endurance, flame spread, or smoke and toxicity criteria, the following requirements apply:

X2.3.1.1 Pipes shall be delivered from the manufacturer with the protective coating on. On site application will be limited to what is physically necessary for installation (that is, joints).

X2.3.1.2 The fire-protection properties (that is, fire endurance, flame spread, smoke production, and so forth) of the coating shall not be diminished when exposed to (1) salt water, oil, or bilge slops, (2) other environmental conditions such as high and low temperatures, high and low humidity, and ultraviolet rays, or (3) vibration.

X2.3.1.3 The adhesion qualities of the coating shall be such that the coating does not flake, chip, or powder, when subject to an adhesion test.

X2.3.1.4 The fire-protective coating shall be resistant to impact and abrasion. It shall not be separated from the piping during normal handling.

X2.4 General Fire Endurance Test Requirements:

X2.4.1 All typical joints, including but not limited to pipe to pipe, fiberglass flange to fiberglass flange, and fiberglass flange to metallic flange intended to be used shall be tested. Elbows and tees need not be tested provided the same adhesive or method of joining utilized in straight piping tests will be used in the actual application.

X2.4.2 Qualification of piping systems of sizes different than those tested shall be allowed as provided for in **Table X2.1**. This applies to all pipe, fittings, system joints (including

TABLE X2.1 Qualification of Piping Systems of Different Sizes

| Size Tested [NPS], in. (mm) | Minimum Size Approved, in. (mm) | Maximum Size Approved, in. (mm) |
|--------------------------------|---------------------------------------|---------------------------------------|
| 0 to 1.5 (0 to 40) | size tested | size tested |
| 2 to 4 (50 to 100) | size tested | 4 (100) |
| 5 to 10 (125 to 250) | size tested | 10 (250) |
| 12 to 22 (300 to 550) | size tested | 22 (550) |
| 24 to 34 (600 to 850) | size tested | 34 (850) |
| 36 to 48 (900 to 1200) | size tested | 48 (1200) |

joints between metal and fiberglass pipes and fittings), methods of joining, and any internal or external liners, coverings, and coatings required to comply with the performance criteria.

X2.4.3 No alterations to couplings, fittings, joints, fasteners, insulation, or other components shall be made after the commencement of the fire endurance testing. Flange bolts shall not be retorqued after completion of the fire exposure testing, before hydrostatic testing. Postfire hydrostatic testing shall be conducted without altering the component in any way.

X2.5 *Fire Type JF—Jet Fire*—This test is based upon Health & Safety Executive document OTI 95 634, except that is modified so that actual pipe, joints, and fittings are exposed to the flame.

X2.5.1 Equipment:

X2.5.1.1 A propane vaporization and propulsion system capable of delivering 0.66 ± 0.11 lb/s (0.3 ± 0.05 kg/s) flow under controlled conditions into a backing “box” which has the test specimen mounted at the box’s front opening. The nozzle shall be a tapered, converging type, 7.875 in. (200 mm) in length with an inlet diameter of 2.0 in. (52 mm) and an outlet diameter of 0.70 in. (17.8 mm). The nozzle is to be located 3.281 ft (1.0 m) from the front of the box, centered across the box, and mounted horizontally between 15 in. (375 mm) and 30 in. (750 mm) from the bottom of the box. The flow shall directly impinge on the test specimen.

X2.5.1.2 Water-handling and timing equipment suitable for delivering sufficient quantities of water to produce a fluid velocity of 3 ft/s (0.91 m/s) at the rated pressure of the piping system being tested.

X2.5.1.3 Instrumentation to record fuel flow rate, water flow rate, temperatures in the specimen and in various locations in the backing panel, and water leakage rate from the pipe assembly or individual components.

X2.5.2 Test Specimen—The test specimen shall be prepared with the joints, fittings, and fire-protection coverings, if any, intended for use in the proposed application. It is up to the authority having jurisdiction to determine the number and size of test specimens, as well as requirements for the qualification of a range of pipe diameters.

X2.5.3 Test Conditions:

X2.5.3.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature at 50 % relative humidity of $70 \pm 10^\circ\text{F}$ ($20 \pm 5^\circ\text{C}$). Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the coatings' or coverings' properties should not degrade over time or due to exposure to the environment as discussed in IMO FTP Code Res A.753(18) Paragraph 2.2.6, or both.

X2.5.3.2 The test specimen shall be planar and shall be mounted flush to the opening of a 5 by 5-ft (1.5 by 1.5-m) open-ended, steel box (closed back panel with a depth of 1.64 ft (0.5 m). Suitable auxiliary equipment shall be attached to the box to ensure the box's structural stability and to prevent any transient ambient conditions from significantly affecting the testing. The purpose of the box is to provide a "backstop" to the flame and cause swirling of the fire to completely engulf the sample.

X2.5.3.3 If required to record temperature conditions during testing, mount thermocouples on the specimen and within the box or its structure.

X2.5.3.4 The test building shall be suitably constructed to ensure there is not a hazardous amount of heat or smoke allowed to accumulate during or after the test.

X2.5.3.5 Before conducting the test, calibration runs of the gas flow controls and water flow system shall be conducted.

X2.5.3.6 Fuel used shall be commercial grade propane delivered to the nozzle as a vapor without a liquid fraction.

X2.5.4 Test Procedure:

X2.5.4.1 Pressure test each test specimen to 1.5 times its rated pressure prior to mounting in the test rig. No leakage is allowed during this test.

X2.5.4.2 Unless Fluid S is specified, completely drain the specimen of water after the initial test and secure into position. Make all thermocouple and plumbing connections at this time. For Fluid S conditions, secure the specimen into position filled with water.

X2.5.4.3 It is acceptable to start the test using a small "pilot" flame to ensure safe ignition of the fuel before full flow being established.

X2.5.4.4 Increase the flow to the rate as specified in **X2.5.1.1**. This rate has been shown to produce a heat flux between 95 100 and 126 800 Btu/(h-ft²) (300 and 400 kW/m²). Timing of the test is to begin when the specimen is fully engulfed. Establish fully controlled flow within 30 s of the start of the test.

X2.5.4.5 If Fluid E or S is specified in **4.3.1**, then continue the test for a minimum of 20 min under the initial conditions.

X2.5.4.6 If Fluid EF in **4.3.1** is specified, take the following steps:

(1) Continue the test in the dry condition for 5 min.

(2) After the 5-min dry period, introduce water at a flow velocity not to exceed 3.0 ft/s. Pressure in the system is to be maintained at a minimum of 90 % of the rated pressure for the system. These conditions are to be established within 1 min after the flow of water begins.

(3) Continue the test under flowing water conditions for a minimum of 15 min.

X2.5.4.7 Increased exposure times over those previously specified are acceptable upon agreement between the manufacturer and the buyer.

X2.5.4.8 Upon completion of the fire exposure period, discontinue the fuel flow, extinguish the flame, and allow the sample to cool (with flowing water, if desired) to room temperature.

X2.5.4.9 After cooling, pressurize the specimen at its rated pressure for a minimum of 15 min with stagnant water (make-up water is allowed). Measure overall leakage and leakage of each component and record after this period.

X2.5.5 Acceptance Criteria—Piping shall be deemed to have passed the test if the performance meets the criteria set by the authority having jurisdiction regarding integrity and duration in **4.3.3**. If no criteria is established, a maximum leakage of 10 % of the rated flow will be used as the default limit.

X2.5.6 Report—Report the following information:

X2.5.6.1 Complete identification of the pipe or fitting tested including the manufacturer's name and code.

X2.5.6.2 Description of fire-protective coating, if applicable.

X2.5.6.3 Diameter of pipe, fitting, or joint.

X2.5.6.4 Endurance time.

X2.5.6.5 Appearance of test specimen.

X2.5.6.6 Date of test.

X2.5.6.7 Leakage rate.

X2.6 Fire Type HF—Hydrocarbon Furnace Test Method—This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications. The procedure in Test Method **E1529** with additional steps as outlined shall be followed. This procedure is similar to IMO Assembly Resolution A.753(18), Appendix 1, which is an alternative to this test.

X2.6.1 Significance—This test method is intended to provide a basis for evaluating the time period during which fiberglass pipe will continue to perform its intended function when subjected to a controlled, standardized fire exposure. In particular, the standard exposure condition of Test Method **E1529** simulates the condition of total continuous engulfment of a pipe or piping system in the luminous flame (fire plume) area of a large, free-burning hydrocarbon pool fire. The standard fire exposure is defined in terms of the total flux incident on the test specimen together with the appropriate temperature conditions.

X2.6.2 Test Equipment:

X2.6.2.1 Furnace—The setup and control of the test shall be as specified in Sections 6 through 11 of Test Method **E1529**.

X2.6.2.2 Nitrogen tank with regulator or water circulating system with flow meters.

X2.6.3 Test Specimen:

X2.6.3.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature at 50 % relative humidity of $70 \pm 10^\circ\text{F}$ ($20 \pm 5^\circ\text{C}$). Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the coatings or coverings properties should not degrade over time or due to exposure to the environment as discussed in IMO FTP Code Res A.753(18) Paragraph 2.2.6, or both.

X2.6.3.2 Accelerated conditioning is permissible provided the test method does not alter the properties of component materials.

X2.6.3.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. Construct these samples in such a way as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

X2.6.3.4 Prepare the test specimen with the joints, fittings, and fire-protection coverings, if any, intended for use in the proposed application.

X2.6.3.5 The number of specimens shall be sufficient to test typical joints as noted in X2.4.1.

X2.6.3.6 For specimens to be tested using Fluid E, the ends of the specimen shall be closed with one end allowing pressurized nitrogen to be connected. Specimens to be tested with Fluid EF and S shall have both ends closed with means to connect the water supply.

X2.6.3.7 It is permissible for the pipe ends and closures to be outside the furnace.

X2.6.3.8 The general orientation of the specimen shall be horizontal and it shall be supported by one fixed support. Remaining supports shall allow free movement.

X2.6.3.9 Special samples shall be used for moisture content determination and conditioned with the test specimen. Construct these samples so as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

X2.6.3.10 When testing with Fluid E, nitrogen pressure inside the test specimen shall be maintained automatically at 10.1 ± 1.5 psi (0.7 ± 0.1 bar) during the test. Means shall be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen to indicate leakage.

X2.6.4 Procedure:

X2.6.4.1 Measure the dimensions of the specimen in accordance with Practice D3567. Include measurements of liner thickness and external coatings, if applicable.

X2.6.4.2 Place specimen in the furnace.

X2.6.4.3 Pressurize specimens to be tested with Fluid E with nitrogen maintaining the pressure in accordance with X2.6.3.10. Specimens to be tested with Fluid EF shall be initially filled with ambient air for 5 min and then with water flowing with a maximum velocity of 3 ft/s and 44 ± 7 psi (3 ± 0.5 bar). Specimens to be tested with Fluid S shall be filled with water at 44 ± 7 psi (3 ± 0.5 bar).

X2.6.4.4 Subject the piping or piping system to the fire exposure specified in Section 6 of Test Method E1529 for the time specified by the authority having jurisdiction.

X2.6.4.5 After termination of the furnace test, allow the specimen, together with any fire-protective coating, to cool in still air to ambient temperature and then test to the rated pressure for 15 min.

X2.6.5 *Acceptance Criteria*—Pipe shall be deemed to pass the test if the performance meets the customer specified integrity/duration in 4.3.3. Note that, to meet IMO A753(18), Level 1 or Level 2 requirements, Fluid E shall be tested and there shall be no nitrogen leakage during the test or water leakage during the hydrotest in X2.6.4.5. For Level 1 or Level 2, the duration of the test is 60 or 30 min, respectively.

X2.6.6 *Report*—Report the following information:

X2.6.6.1 Complete identification of the pipe or fitting tested including manufacturer's name and code.

X2.6.6.2 Description of fire-protective coating, if applicable.

X2.6.6.3 Diameter of pipe, fitting, or joint.

X2.6.6.4 Endurance time.

X2.6.6.5 Appearance of test specimen.

X2.6.6.6 Date of test.

X2.7 Fire Type IF—Impinging Flame:

X2.7.1 *Scope*—This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications. This test procedure is based on the IMO Assembly Resolution A.753(18) Appendix 2, which is an alternate procedure.

X2.7.2 *Summary of Test Method*—This test method subjects a pipe sample to a constant $36\,011\text{-Btu}/(\text{h}\cdot\text{ft}^2)$ ($113.6\text{-kW}/\text{m}^2$) net flux to determine a pipe systems fire-endurance.

X2.7.3 Test Equipment:

X2.7.3.1 *Sievert No. 2942 Burner or Equivalent*, which produces an air mixed flame. Propane with a minimum purity of 95 % should be used.

(1) The inner diameter of the burner heads shall be 1.14 in. (29 mm).

(2) The burner heads shall be mounted in the same plane and supplied with gas from a manifold (see Fig. X2.1).

(3) Each burner shall be equipped with a valve, if necessary, to adjust the flame height.

(4) It is acceptable to use a burner stand or pipe supports with an adjustable height.

(5) The distance between the burner heads and the pipe shall be maintained at $5 \pm \frac{3}{8}$ in. (125 ± 10 mm) during the test.

(6) The free length of pipe between supports shall be 31.5 ± 2 in. (800 ± 50 mm).

X2.7.3.2 *Thermocouples*—Two thermocouples capable of measuring up to 2012°F (1100°C).

X2.7.3.3 *Water*.

X2.7.3.4 *Thermometer*, to measure internal water temperature.

X2.7.3.5 *Pressure Gage*, which is capable of reading up to 73 psi (5 bar) ± 5 %.

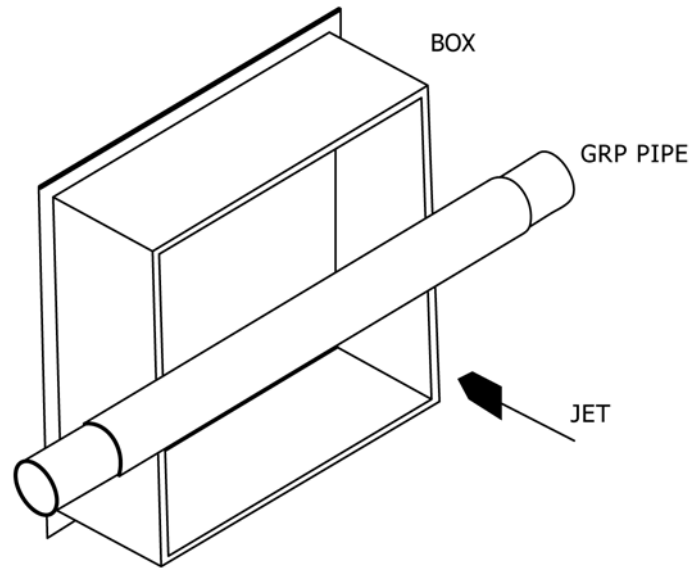


FIG. X2.1 Basic Layout of a Jet Fire Test

X2.7.3.6 *V-shaped Pipe Supports*, two.

X2.7.4 *Test Specimen:*

X2.7.4.1 The test specimen shall be 59 in. (1.5 m) long.

X2.7.4.2 Pipe with permanent joints or fittings intended for use in marine applications shall be used in the specimen.

X2.7.4.3 All joint types shall be tested as noted in X2.4.1.

X2.7.4.4 The quantity of pipe specimens shall be sufficient to test all typical joints and fittings.

X2.7.4.5 A pressure relief valve shall be connected to one of the end closures of the system.

X2.7.5 *Test Conditions:*

X2.7.5.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature at 50 % relative humidity of $70 \pm 10^\circ\text{F}$ ($20 \pm 5^\circ\text{C}$). Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the coatings' or coverings' properties should not degrade over time or as a result of exposure to the environment as discussed in IMO FTP Code Res A.753(18) Paragraph 2.2.6, or both.

X2.7.5.2 Accelerated conditioning is permissible provided the test method does not alter the properties of component materials.

X2.7.5.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. Construct these samples so as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

X2.7.5.4 The test shall be carried out in a sheltered test site to prevent any draft from influencing the test.

X2.7.5.5 Specimens to be tested with Fluid E shall be pressurized with nitrogen maintaining the pressure in accordance with Appendix X2. Specimens to be tested with Fluid EF shall be initially filled with ambient air for 5 min and then with water flowing with a maximum velocity of 3 ft/s and 44 ± 7 psi

(3 ± 0.5 bar). Specimens to be tested with Fluid S shall be filled with water at 44 ± 7 psi (3 ± 0.5 bar).

X2.7.5.6 The water temperature when testing with Fluids S and EF shall not be less than 59°F (15°C) at the start of the test and shall be measured at a maximum of 5-min intervals during the test.

X2.7.5.7 *Flame Temperature:*

(1) The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (25 mm) from the pipe near the center span of the assembly.

(2) The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

(3) The test temperature shall be taken as the average of the two thermocouple readings.

X2.7.6 *Procedure:*

X2.7.6.1 Measure the dimensions of the specimen in accordance with Practice D3567. Include measurements of liner thickness and external coatings, if applicable.

X2.7.6.2 Place the specimen on two V-shaped supports. The two stands shown in Fig. X2.1 are permissible supports.

X2.7.6.3 Pressurize the specimen with water as required in accordance with 4.3.1.

X2.7.6.4 *Burner Configuration for Constant Heat Flux:*

(1) For piping 6 in. or less in diameter, the fire source shall consist of two rows of 5 burners as shown in Fig. X2.2.

(2) A constant heat flux averaging $36\,011\text{ Btu}/(\text{h}\cdot\text{ft}^2)$ ($113.6\text{ kW}/\text{m}^2$) $\pm 10\%$ shall be maintained $5 \pm \frac{3}{8}$ in. (125 ± 10 mm) above the centerline of the array.

(a) This flux corresponds to a premix flame of propane of a minimum 95 % purity with a fuel flow rate of 11.02 lb/h (5 kg/h) for a total heat release of 221 780 Btu/h (65 kW).

(b) The gas consumption shall be measured with an accuracy of $\pm 3\%$ in order to maintain a constant heat flux.

(3) For piping greater than 6 in. in diameter, one additional row of burners shall be included for each 2-in. increase in diameter while maintaining the heat flux in X2.7.6.4.

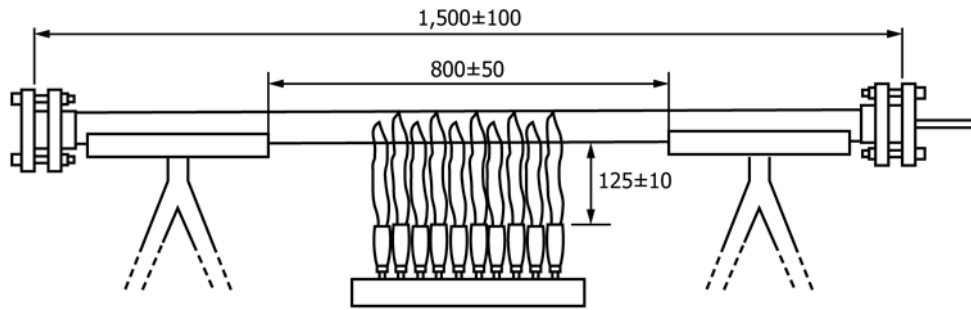


FIG. X2.2 Basic Layout of an Impinging Flame Test

(4) Begin the heat flux.

(5) Record the test temperature and water temperature and pressure, if applicable, at the beginning of the test, at the end of the test, and at maximum 5-min intervals during the test.

X2.7.6.5 Expose the test specimen to flame for 30 min.

X2.7.6.6 After termination of the burner regulation, test the test sample, together with the fire-protective coating, if any, shall be allowed to cool to ambient temperature and then tested to the rated pressure of the pipe. If fire-protective coverings are used, then conduct the pressure test without the covering, where practical.

(1) Hold the pressure for a minimum of 15 min.

X2.7.7 *Acceptance Criteria*—Piping shall be deemed to have passed the test if the performance meets the criteria set by the authority having jurisdiction regarding integrity and duration in 4.3.3.

X2.7.8 *Report*—Report the following information:

X2.7.8.1 Complete identification of the pipe or fitting tested including the manufacturer's name and code.

X2.7.8.2 Description of fire-protective coating, if applicable.

X2.7.8.3 Diameter of pipe, fitting, or joint.

X2.7.8.4 Endurance time.

X2.7.8.5 Appearance of test specimen.

X2.7.8.6 Date of test.

X2.7.8.7 Leakage rate.

X2.8 *Flame Spread:*

X2.8.1 Flame spread testing of fiberglass piping shall be conducted in accordance with Appendix 3 of IMO Resolution A.753(18) except as modified in X2.8.2.

X2.8.2 Testing need not be conducted on all piping sizes. Only the sizes with the maximum and minimum wall thickness to be used must be tested.

X2.9 *Smoke and Toxicity:*

X2.9.1 Smoke and toxicity testing of fiberglass piping shall be conducted in accordance with Annex 1, Part 2—Smoke and Toxicity Test, of IMO Resolution MSC.61(67) except as modified in X2.9.2 – X2.9.12. These modifications are similar to those in Appendix 3 of IMO A.753(18) except they apply to the smoke and toxicity test, not the surface flammability test.

X2.9.2 Testing shall be conducted on piping sizes with the maximum and minimum wall thickness intended to be used.

X2.9.3 The test sample shall be fabricated by cutting pipes lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. All cuts shall be made normal to the pipe wall.

X2.9.4 The number of sections that must be assembled together to form a square test sample with sides measuring 3 in. shall be that which corresponds to the nearest integral number of sections which will result in a test sample with an equivalent linearized surface width between 3 and 3.5 in. The surface width is defined as the measured sum of the outer circumference of the assembled pipe sections normal to the lengthwise sections.

X2.9.5 The assembled test sample shall have no gaps between individual sections.

X2.9.6 The assembled test sample shall be constructed in such a way that the edges of two adjacent sections will coincide with the centerline of the test holder.

X2.9.7 The test samples shall be mounted on calcium silicate board and held in place by the edges of the test frame and, if necessary, by wire.

X2.9.8 The individual pipe sections shall be mounted so that the highest point of the exposed surface is in the same position as the plane of an equivalent flat plate.

X2.9.9 The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board shall be left void.

X2.9.10 The void space between the top of the exposed test surface and the bottom edge of the sample holder frame shall be filled with a high-temperature insulating wool where the pipe extends under the frame.

X2.9.11 When the pipes are to include fireproofing or coatings, the composite structure consisting of the segmented pipe wall and fire proofing shall be tested and the thickness of the fireproofing shall be the minimum thickness specified for the intended usage.

X2.9.12 The test sample shall be oriented in the apparatus such that the pilot burner flame will be normal to the lengthwise piping sections.

X3. ELECTRICAL PROPERTY TEST METHODS FOR CONDUCTIVE FIBERGLASS PIPING

X3.1 *Test Method for Determination of Charge Shielding Properties of Reinforced Thermosetting Resin Pipe, Fittings, and Joints:*

X3.1.1 *Summary of Test Method*—In this test method, a high-voltage electric field is applied to the interior surface of a grounded reinforced thermosetting resin pipe, fitting, or joint, and the resulting voltage on the exterior surface, if any, is measured. This test can also be used to determine the effect of typical chemical exposure on the conductive properties of the pipe, fittings, and joints.

X3.1.2 *Test Equipment:*

X3.1.2.1 *DC Supply*, capable of producing a minimum voltage of 1000 V.

X3.1.2.2 *Fieldmeter*, capable of measuring and displaying electric fields values of $100 \text{ V}\cdot\text{m}^{-1}$ with zero stable within $50 \text{ V}\cdot\text{m}^{-1}$ over at least 1000 s. A reading of $100 \text{ V}\cdot\text{m}^{-1}$ shall be at least 10 % of an analog scale reading or at least the second digit of a digital display. The instrument display shall give a linear response to electric field, symmetric with polarity and with no hysteresis. These properties shall be within 5 % of full-scale reading of the operating range. The output time constant at the display shall be less than 1 s.

X3.1.3 *Sample Preparation:*

X3.1.3.1 The minimum NPS of the pipe, fitting, or joint tested shall be 2.

X3.1.3.2 For pipe specimens, the minimum length of the sample shall be seven times the NPS.

X3.1.3.3 If necessary to provide space for a grounding clamp, add further sections of conductive pipe, as necessary, to the specimen using the manufacturer's normally recommended assembly methods for conductive joints. If a joint is required, then the resistance across the joint shall be determined in accordance with X3.2.

X3.1.3.4 Identify a minimum of five locations on the outside of the component for positioning the fieldmeter. Ensure that the locations around the periphery are equally spaced over the length of the component. It is possible that additional locations are needed to account for regions where there is a change in component geometry.

X3.1.4 *Conditioning:*

X3.1.4.1 The test specimen shall not be tested until the material has reached an air-dry condition. This condition is defined as 16 to 24 h at an ambient temperature of $73.4 \pm 3.6^\circ\text{F}$ ($23 \pm 2^\circ\text{C}$) and $50 \pm 5\%$ relative humidity.

X3.1.4.2 If the effect of the environment on the electrical properties is required, place the specimens in a test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 60 to 80°F (15 to 27°C) throughout the test.

(1) At the end of three months, remove the test specimen from the tank and rinse thoroughly with tap water if the specimen has been exposed to a water-soluble product or a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

(2) Wipe dry and place the test specimen in an oven at $149 \pm 10^\circ\text{F}$ ($65 \pm 5^\circ\text{C}$) for a period of 2 h.

(3) Remove the specimen from the oven and allow it to cool to 70 to 80°F (21 to 27°C) in a $50 \pm 5\%$ relative humidity environment for 16 to 24 h.

X3.1.5 *Procedure:*

X3.1.5.1 Install a grounding clamp of the earthing system on the exterior of the specimen at each end of the component in accordance with the manufacturer's instructions. Any surface preparation shall not exceed that normally required when installing a piping system.

X3.1.5.2 Blank off each termination of the specimen assembly with a suitable removable plug made from an insulating material which is in contact with just the inside surface of the component. One of the plugs shall be provided with an electrode that passes through the thickness of the material. For fittings, this electrode shall be a minimum distance of 12 in. (305 mm) away from the main body of the fitting. An additional section of conductive pipe shall be added as necessary to the component in accordance with X3.1.3.3.

X3.1.5.3 Completely fill the inside of the specimen with a suitable conducting fluid. It is acceptable to fit one or more of the plugs with a vent fitting to enable air to be expelled. Ensure the outside of the specimen is dry.

X3.1.5.4 Position the specimen vertically on a nonconducting surface or suspend it with non-electrically conducting materials in a manner to ensure that the outside of the component under test is accessible on all sides. The plug with the electrode shall be positioned such that the inside is in contact with the conducting fluid.

X3.1.5.5 Connect the electrode in the plug to the dc supply.

X3.1.5.6 Position the fieldmeter 1 in. (25 mm) from the exterior surface of the component under test. The fieldmeter shall be a minimum distance of 12 in. (305 mm) away from the wire connecting the dc supply to the electrode in the plug.

X3.1.5.7 With the specimen connected to earth using the grounding clamp, turn the dc supply on and monitor the output of the fieldmeter for 1 min. Turn off the dc supply.

X3.1.5.8 Repeat X3.1.5.6 and X3.1.5.7 for the remaining test positions.

X3.1.6 *Report*—Report the following information:

X3.1.6.1 Manufacturer of pipe, fitting, or joint.

X3.1.6.2 Designation of the product being tested.

X3.1.6.3 Description of the test sample including diameter of pipe, fitting, or joint and lengths of pipe extenders, if used.

X3.1.6.4 Description of grounding details.

X3.1.6.5 Test media if exposure is done.

X3.1.6.6 Conducting fluid used.

X3.1.6.7 dc supply voltage.

X3.1.6.8 Record of voltage output from the fieldmeter for 1 min for each test position and after exposure for one, three, six, and twelve months when exposure testing is done.

X3.1.6.9 Appearance of test specimen.

X3.1.6.10 Date.

X3.2 Test Method for Determining the Electrical Resistance Per Unit Length of Fiberglass Pipe, Fittings, Joints, and Representative Piping Systems:

X3.2.1 Summary of Test Method—In this test method, the length of the potential current path is measured and then the resistance is determined using a suitable megohmmeter capable of measuring resistance between 2000 and $1 \times 10^{10} \Omega$. The test method is also useful to determine the effect of typical chemical exposures on the conductive properties of the pipe. The results are expressed in terms of resistance per unit length.

X3.2.2 Test Equipment:

X3.2.2.1 Megohmmeter, capable of measuring resistance between 2000 and $1 \times 10^{10} \Omega$ with a resolution of 5 %. The voltage between the electrodes shall be a minimum of 500 V.

X3.2.3 Test Specimen:

X3.2.3.1 Pipe.

(1) The pipe length shall be 3.28 ft (1 m) or six times the nominal diameter of the product plus two times the width of the grounding clamps, if applicable, whichever is greatest.

X3.2.3.2 Pipe with Fitting or Joint, or Both:

(1) NPS 2 piping shall be used unless otherwise specified.
 (2) The electrical construction of the pipe shall be consistent with that of the fitting and joint.

(3) The joint or fitting shall be attached to two lengths of pipe. It is possible that this will require some fittings, for example, flanges, to be assembled in pairs. The length of each pipe shall be six times the nominal diameter of the product plus one times the width of the grounding clamps, if applicable. If needed to achieve this length, add further sections of conductive pipe using the manufacturer's recommended assembly methods.

X3.2.4 Conditioning—The test specimen shall not be tested until the material has reached an air-dry condition. This condition is defined as 16 to 24 h at an ambient temperature of $73.4 \pm 3.6^\circ\text{F}$ ($23 \pm 2^\circ\text{C}$) and $50 \pm 5\%$ relative humidity.

X3.2.5 Procedure:

X3.2.5.1 Where the electrical conductivity properties of the pipe and joint/fitting combination is to be evaluated, first determine the electrical properties of the pipe on its own.

X3.2.5.2 Current Path Selection—The current paths of interest are as follows:

(1) Inside surface of the pipe at one end of the test assembly to the outside surface of the pipe at the other end of test assembly.

(2) Outside surface of the pipe at one end of the test assembly to the outside surface of the pipe at the other end of test assembly.

X3.2.5.3 Sample Preparation:

(1) Attach a suitable electrode (see **Note X3.1**) or grounding clamp to the outside diameter of a pipe on one end of the pipe or assembly.

(2) Where a grounding clamp is applied, the surface preparation shall not exceed that used when piping systems are installed in accordance with the manufacturer's recommendations.

(3) Apply two suitable electrodes, one around the interior circumference of the specimen and one around the exterior

circumference, on the other end of the pipe or assembly. Where the test is being carried out to confirm continuity of the embedded conducting elements within the component body, it is permissible to use the exterior electrode as a grounding clamp that is applied in a similar manner to the first.

(4) The distance of the electrodes from the end of the specimen shall be greater than or equal to twice the specimen thickness. The width of the electrodes shall be between four and six times the specimen wall thickness.

NOTE X3.1—A suitable electrode shall provide the necessary conductivity to the surface of the pipe without causing damage to the surface. Examples include conductive paints, conductive adhesive tape, and brine-soaked sponges held in place with clamps.

X3.2.5.4 Outside-to-Outside Surface Electrical Measurement:

(1) Isolate the test specimen from ground.

(2) Attach suitable wires to the two external electrodes.

(3) Determine the resistance using the megohmmeter.

(4) The power applied neither should exceed 3.41 Btu/h (1W), and the electrification time shall not exceed one minute unless otherwise specified. Record the readings from the megohmmeter and its accuracy at that range.

(5) If the effect of the environment on the electrical properties is required, place the specimens in the test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 59 to 80°F (15 to 27°C) throughout the test. At the end of three months, remove the test specimen from the bath and rinse thoroughly with tap water if the specimen has been exposed to a water soluble product or a hydrocarbon solvent if the specimen has been exposed to a petroleum product. Wipe dry and place the test specimen in an oven at $149 \pm 9^\circ\text{F}$ ($65 \pm 5^\circ\text{C}$) for a period of 2 h. Remove the specimen from the oven and allow it to cool to 70 to 80°F (21 to 27°C) in a $50 \pm 5\%$ relative humidity environment for 16 to 24 h. Determine the resistance using the megohmmeter. Note the appearance of the test specimen and the condition of the clamps.

X3.2.5.5 Inside-to-Outside Surface Electrical Measurement:

(1) Isolate the test specimen from ground.

(2) Attach suitable wires to the internal and external electrode.

(3) Carry out the procedure in accordance with **X3.2.5.4**.

X3.2.6 Calculation of Pipe and Joint/Fitting Electrical Resistance:

X3.2.6.1 The electrical resistance shall be calculated for the two cases:

(1) External-to-external surface of the component.

(2) External-to-internal surface of the component.

X3.2.6.2 Care shall be taken to ensure that these two situations are treated separately.

X3.2.6.3 For the pipe tested on its own, the resistance per unit length of pipe shall be calculated by dividing the resistance of the pipe by the length between electrodes.

X3.2.6.4 The resistance of the fitting or joint shall be calculated as follows:

(1) Calculate the resistance of each length of pipe attached to the joint or fitting by multiplying the resistance per unit length by the distance from the electrode to the fitting/joint.

(2) Subtract two times the pipe resistance from the overall resistance measured across the assembly to give the resistance across the coupling.

X3.2.6.5 The resistance per unit length shall be determined by dividing the resistance by the effective path length. The effective path length depends on the type of fitting and mode tested.

X3.2.6.6 For pipes, straight joints, adapters, couplings, plugs, caps, and bushings, the path length shall be parallel to the centerline axis of the component and shall encompass the length of the component.

X3.2.6.7 For elbows, the path length shall be the length of the component at the mid-bend radius.

X3.2.6.8 For crosses and tees, one path length shall be parallel to the centerline axis of the component and shall encompass the length of the component. The other path length shall be along the shortest path from adjacent openings through each 90° bend.

X3.2.6.9 For laterals, one path length shall be parallel to the centerline axis of the component and shall encompass the

length of the component. The second path length shall be along the shortest distance between adjacent openings through the oblique angle. The third path length shall be along the shortest distance between adjacent openings through the obtuse angle.

X3.2.7 *Report*—Report the following information:

X3.2.7.1 Complete identification of the pipe and fitting/joint/fire-protection coating tested including the manufacturer's name and code.

X3.2.7.2 Diameter of the pipe, fitting, or joint.

X3.2.7.3 Details of the megohmmeter including name and model number, resolution capability, and voltage applied.

X3.2.7.4 Mode of testing, that is, external surface-to-external surface or external surface-to-internal surface and whether grounding clamps were used.

X3.2.7.5 Results of testing:

(1) Resistance per unit length of pipe.

(2) Resistance of fitting/joint.

X3.2.7.6 Environmental exposure time and media where applicable.

X3.2.7.7 Appearance of specimen.

X3.2.7.8 Date of test.

X4. SUPPLEMENTARY REQUIREMENTS FOR U.S. NAVY USE

X4.1 *Scope*—This appendix shall be applied only when specified by the purchaser in the inquiry, contract, or order. This appendix contains special material, design, and performance considerations and supplemental tests required when fiberglass piping is to be used for U.S. Navy applications. These requirements shall in no way negate any requirement of the specification itself.

X4.2 *Special Material, Design, and Performance Considerations:*

X4.2.1 Unless otherwise specified in the ordering information, fiberglass pipe and fittings shall be rated for a minimum of 200-psig static pressure at a minimum of 150°F.

X4.2.2 *Physical Properties*—Pipe and fittings shall have the physical properties outlined in this section. Unless otherwise specified in the ordering information, all physical properties shall be determined at no less than 75°F.

X4.2.2.1 *Cyclic Pressure Strength*—Pipe, fittings, and adhesive bonded joints shall be cycled a minimum of 10 000 cycles with no signs of leakage or weeping when tested in accordance with X4.3.2.

X4.2.2.2 *Hydrostatic Strength*—Pipe, fittings, and joints shall show no signs of leakage or weeping when tested in accordance with X4.3.3.

X4.2.2.3 *Ultimate Tensile Strength*—The minimum longitudinal tensile strength of sample pipe shall be 8500 psi at 75°F or higher when tested in accordance with Test Method D2105.

X4.2.2.4 *Beam Elastic Modulus*—The minimum elastic modulus of pipe shall be 1 000 000 psi at 150°F when determined in accordance with Specification D5686.

X4.2.2.5 *Hydrostatic Burst Strength*—The minimum hoop tensile strength of pipe shall be 30 000 psi at 75°F when tested in accordance with Test Method D1599.

X4.2.2.6 *Low-Cycle Mechanical Fatigue*—Piping assemblies shall successfully pass the mechanical fatigue test outlined in X4.3.3.4 with no visible signs of leakage.

X4.2.3 No asbestos is permitted in the construction of pipe or fittings.

X4.3 *Supplemental Test Methods*—Supplemental test methods shall be conducted at a laboratory satisfactory to the customer and shall consist of the following test methods.

X4.3.1 *Cyclic Pressure Strength*—Test specimens shall include a tee, a flange, and one other fitting selected by the supplier. The fitting shall be joined to pipe sections at least 18 in. long or three diameters, whichever is longer, using the joining method, construction, and adhesion intended for field assembly. Specimen diameters for testing in each configuration shall include the maximum product size for each method of construction. In addition, the following other sizes shall be tested:

| Product Size Range (NPS) | Test Specimen (NPS) |
|--------------------------|---------------------|
| 1, 1½, 2, 3 | 3 |
| 4, 6 | 6 |
| 8, 10, 12 | 12 |

In each range of product size, the supplier is permitted to select to test a smaller product size to qualify only the smaller size. Each assembly shall be cycled at pressures between 0 psig and two times the static pressure rating for a minimum of 10 000 cycles without failure. Failure shall be classified as any leakage or weeping from the pipe, fitting, or joint.

X4.3.2 *Hydrostatic Strength*—Test specimens shall include a tee, a flange, and one other fitting selected by the supplier. The fitting shall be joined to pipe sections at least 18 in. long or three diameters, whichever is longer, using the joining method, construction, and adhesion intended for field assembly. Specimen diameters for testing in each configuration shall include the maximum product size for each method of construction. In addition, the following other sizes shall be tested:

| Product Size Range (NPS) | Test Specimen (NPS) |
|--------------------------|---------------------|
| 1, 1½, 2, 3 | 3 |
| 4, 6 | 6 |
| 8, 10, 12 | 12 |

In each range of product size, the supplier is permitted to select to test a smaller product size to qualify only the smaller size. Each assembly shall be subjected to a pressure of two times the static pressure rating for 5 min, followed by a pressure drop to 0 psig, and then a repressurization to four times the static pressure rating for a minimum of 5 min.

X4.3.3 *Low-Cycle Mechanical Fatigue Endurance Test Method*—The purpose of this test method is to verify the integrity of the piping system when it is subjected to external mechanical fatigue loads and to demonstrate adequate pipe fatigue endurance under cyclic mechanical loading. The load values for this test have been derived from past successful performance in marine applications.

X4.3.3.1 This test method shall be performed on 1, 3, and 6 NPS assemblies which will qualify piping up to 8 NPS. If qualification for only one size is required, the supplier is permitted to test that size.

X4.3.3.2 A test assembly and apparatus shall be fabricated as shown in Fig. X4.1. The assembly shall consist of a flange, a vertical leg of pipe with a coupling at midspan, a 90° elbow, and a horizontal leg of pipe terminating at a second flange. The total length of the vertical leg from the base of the flange to the centerline of the horizontal leg shall be 10 to 15 times the nominal pipe diameter. The total length of the horizontal leg from the centerline of the coupling arm to the vertical leg shall

be one half of the vertical leg length. Fittings shall be attached to the pipe using the joining method, construction, and adhesion intended for field assembly. If more than one type of fitting (that is, Type I and III in accordance with 4.1.1) is intended for qualification, then each type of fitting must be represented.

X4.3.3.3 The fiberglass pipe assembly shall be fitted with a minimum of six strain gages in the following locations on the “outside” of the vertical leg (the side of the pipe which is subjected to tensile stress/strain when the horizontal leg is displaced downward):

- (1) Within ½ in. of the bottom flange.
- (2) Within ½ in. of the top of the coupling.
- (3) Within ½ in. of the bottom of the coupling.
- (4) Within ½ in. of the 90° elbow.
- (5) Midway between the coupling and the 90° elbow.
- (6) Midway between the coupling and the bottom flange.

These locations are shown in Fig. X4.1. All gages are to be mounted in-line, to within ±5°, with the vertical pipe axis to measure axial strain along the vertical pipe leg. The surface of the pipe wall shall be lightly sanded to remove surface roughness at the gage location before installing the gages.

NOTE X4.1—The following procedure for fully reversed bending ignores (1) the effect of Poisson’s ratio as a result of pressure in calculating the axial stress at the pipe wall and (2) the effect of internal pressure on the mean stress of the pipe wall during fully reversed bending. A further simplification assumes that the bending modulus of the pipe is equal to the axial tensile modulus.

X4.3.3.4 After the pipe assembly has been mounted in the test apparatus, adjust the apparatus so that the assembly is subjected to a stress of 7000 psi. This is done in the following manner:

- (1) Pressurize the pipe assembly to 50 (+0/–5) psig.
- (2) Actuate the hydraulic cylinder and displace the horizontal leg of the pipe assembly down to load the vertical pipe leg containing the strain gages under tension.
- (3) Adjust the displacement of the pipe assembly until the average of all the strain gages indicates an axial strain

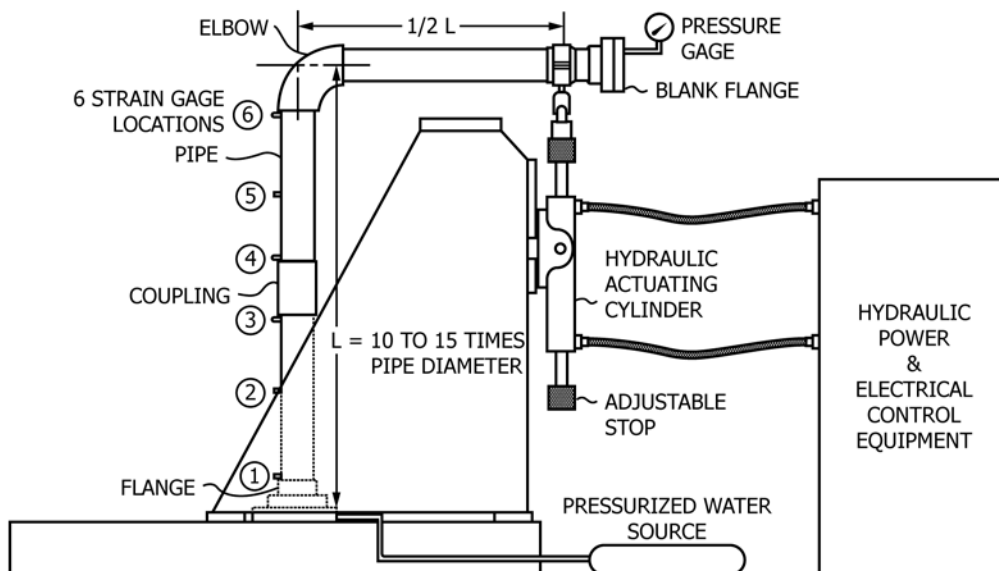


FIG. X4.1 Typical Low-Cycle Mechanical Fatigue Endurance Test Setup

corresponding to a pipe wall stress of 7000 psi. The axial tensile stress can be approximated by multiplying the strain reading by the pipe's axial tensile modulus and ignoring Poisson's effect because of pressure.

(4) Record the strain gage reading and note the actuator displacement.

(5) Reverse the displacement by moving the horizontal leg of the pipe assembly up until the gages registers the equivalent absolute value of stress under compression as previously registered under tension.

(6) Calculate the compressive stress and note the actuator displacement.

X4.3.3.5 Mechanically limit or fix the actuator displacements in the UP and DOWN directions to correspond to the stress values of 7000 psi tensile and 7000 psi compressive.

X4.3.3.6 Begin cycling the actuator and verify that the average of the axial-tensile and compressive strains are repeated at least three times to within $\pm 2\%$.

X4.3.3.7 Cycle the pipe assemblies under fully reversed bending at a rate no greater than 15 cycles per minute for a minimum of 500 cycles or until failure. Failure is defined as the smallest detectable leak, including weeping, from the pipe assembly. Experience has shown that failure often occurs at the strain gage location where the pipe surface has been lightly

sanded. Pipe wall weeping which occurs under maximum stress but stops under reduced stress is still a failure. Any leak from a fitting or adhesive-bonded joint shall constitute a failure. It is likely that all failures will occur in the pipe wall. Note that if data is used from any one test assembly cycled to failure, then all assemblies must be cycled to failure to generate consistent results for graphical plotting and extrapolation.

X4.3.3.8 Record the number of cycles to failure for each size of pipe assembly.

X4.3.3.9 Repeat the procedure with an equivalent stress of 6000 psi with a minimum of 2000 cycles.

X4.3.3.10 Repeat the procedure with an equivalent stress of 4000 psi with a minimum of 50 000 cycles.

X4.3.3.11 Plot the stress versus cycles to failure data on a log-log graph and generate the best-fit straight line through the data using the "least squares" method. It is permissible to extrapolate the data linearly to 100 and 100 000 cycles. The graph shall cover stress from 100 to 10 000 psi and cycles to failure from 100 to 100 000 cycles.

X4.3.3.12 The graphed line must be coincident with or above the following stress values: 6000 psi at 1000 cycles; 4500 psi at 10 000 cycles; and 3400 psi at 100 000 cycles. If the graphed line does not meet these criteria, the test specimen shall be considered to have failed the test.

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