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Standard Specification for Glass Fiber Reinforced Thermoplastic Pipe[1]

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1. Scope*

1.1 This specification covers coiled, machine-made glass fiber reinforced thermoplastic pipe[2] up to 6 in. nominal size, having discrete, unbonded inner and outer layers of thermoplastic compounds and an intermediate structural layer of unbonded, dry glass fiber reinforcement to provide higher strength. Included are a classification system and requirements for materials, mechanical properties, dimensions, performance, methods of test, and marking. Reinforced thermoplastic pipes are used for oil and gas applications, including transport of multiphase fluids, hydrocarbon gases, hydrocarbon liquids and non-potable water.

1.2 The piping system will comprise one or more runs of pipe along with mechanical fittings, designed and for use with this composite pipe, connecting them to each other and to the other pipeline components.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A105/A105M Specification for Carbon Steel Forgings for Piping Applications
A106/A106M Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A333/A333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
A350/A350M Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components
D578 Specification for Glass Fiber Strands
D618 Practice for Conditioning Plastics for Testing
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
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
F412 Terminology Relating to Plastic Piping Systems

2.2 *PPI Standards:*[4]

TR-4 PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.68 on Energy Piping Systems.

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[2] The glass fiber reinforced thermoplastic pipe described in this specification is covered by a patent (US Patents 6,889,716, 6,902,205, and 7,946,629 B2). Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

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

[4] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.

***A Summary of Changes section appears at the end of this standard**

2.3 *ANSI Standards:*[5]
B 16.5 Pipe Flanges and Flanged Fittings

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D883 and F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *glass fiber reinforced thermoplastic pipe, n*—a tubular product comprised of an inner thermoplastic layer reinforced with helically wound un-bonded glass fibers covered with an outer thermoplastic layer.

3.2.2 *inner layer, n*—an inner thermoplastic layer to contain the transported fluid.

3.2.3 *lower confidence limit*—the 95% lower confidence limit of the pressure regression curve, determined as per Practice D2992. Unless otherwise stated, the 95% lower confidence limit is defined at the design life.

3.2.3.1 *Discussion*—For 95% confidence limits, there is a 2.5% probability that the mean value for the regression line may fall above the upper confidence limit and a 2.5% probability that the mean value for the regression line may fall below the lower confidence limit.

3.2.4 *outer layer, n*—an outer thermoplastic layer to protect the reinforcement layer.

3.2.5 *reinforcement layer*—a layer, comprised of un-bonded dry glass fibers helically wound around the inner layer, which provides the strength of the composite pipe.

4. Classification

4.1 *General*—Pipe meeting this specification is classified by pressure design basis and by a cell classification system that defines the basic mechanical properties of the pipe. These pressure design basis categories and cell classification designations are as follows:

4.1.1 *Pressure Design Basis*—Two methods of classifying the pressure design basis of the pipe are provided. Pipe meeting this specification may be classified using either the cyclic test method or the static test method, or both, and the designations are shown in Table 1. Appendix X1 explains how these pressure design basis categories are to be used.

4.1.2 *Mechanical Properties*—Table 2 presents a cell classification system for identifying the mechanical properties of pipe covered by this specification.

NOTE 1—Table 1 and Table 2 simply list possible combinations covered by the above classification system and are not intended to be indicative of commercial availability.

4.1.3 *Pipe Designation Code*—The pipe designation code shall consist of the static or cyclic PDB level in a capital letter and four Arabic numbers identifying, respectively, the cell classification designations of the short-term rupture pressure, longitudinal tensile strength, longitudinal tensile modulus and pipe stiffness.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

TABLE 1 Pressure Design Basis Categories

Cyclic Test Method		Static Test Method	
Designation	Pressure Design Basis, psig (MPa)	Designation	Pressure Design Basis, psig (MPa)
A	315 (2.17)	N	315 (2.17)
B	400 (2.76)	O	400 (2.76)
C	500 (3.45)	P	500 (3.45)
D	630 (4.34)	Q	630 (4.34)
E	800 (5.52)	R	800 (5.52)
F	1 000 (6.89)	S	1 000 (6.89)
G	1 250 (8.62)	T	1 250 (8.62)
H	1 600 (11.0)	U	1 600 (11.0)
I	2 000 (13.8)	V	2 000 (13.8)
J	2 500 (17.2)	W	2 500 (17.2)
K	3 150 (21.7)	X	3 150 (21.7)
L	4 000 (27.6)	Y	4 000 (27.6)

4.1.3.1 *Example:* D1234. Such a designation would describe a glass fiber reinforced thermoplastic pipe having a cyclic pressure design basis of 630 psig (4.34 MPa); a short-term rupture pressure exceeding 1 000 psig (6.89 MPa), a longitudinal tensile strength exceeding 15 000 psi (103 MPa), a longitudinal tensile modulus exceeding 3×10^6 psi (20 700 MPa) and a pipe stiffness exceeding 300 lbf/in^2 (2 069 kPa).

5. Materials and Manufacture

5.1 *General*—The thermoplastic materials, glass fiber reinforcement, colorant, or other materials, or a combination thereof, when combined as piping components, shall produce a pipe system that shall meet the performance requirements of this specification.

5.2 *Pipe layers*—Reinforced Thermoplastic Pipe is a composite pipe product, capable of being made in long continuous lengths and coiled for storage, transport and installation. The first step in the production process is extrusion of a thermoplastic inner layer or barrier to contain the transported fluid and contribute a portion of the mechanical strength. The next step is addition of a structural glass fiber layer over the inner layer to provide the majority of the mechanical strength to withstand the loads applied during service and installation. This structural layer typically consists of an even number of balanced helical windings of continuous glass fiber reinforcement, applied as helically wound unbonded fibers using an automated process control. In the third and final step an outer thermoplastic layer is extruded on top of the structural layer. This outer layer protects the structure during installation and operation, and may help transfer mechanical loads within the end fitting. Mechanical end fittings are used to terminate pipe ends or connect adjacent pipe sections.

5.3 *Materials Selection*—The manufacturer shall be responsible for the selection and supply of all materials so that they meet the specified service and installation requirements. Different material grades can be used in the thermoplastic inner and outer layers provided the combination meets the requirements of this specification.

5.3.1 *Thermoplastic Inner Layer*—The inner layer shall be constructed from polyethylene or crosslinked polyethylene material complying with Specification D3350 and listed in PPI TR-4. Either PE2708, PE3608 or PE4710, as defined and listed in PPI TR-4, with a Specification D3350 minimum cell

TABLE 2 Physical Property Requirements

Designation Order Number	Mechanical Property	0[A]	1	2	3	4	5	6
1	Short-term rupture pressure, min, psig (MPa)	...	1 000 (6.89)	2 000 (13.8)	3 000 (20.7)	4 000 (27.6)	5 000 (34.5)	6 000 (41.4)
2	Longitudinal tensile strength, min, psi (MPa)	...	8 000 (55.2)	15 000 (103)	25 000 (172)	35 000 (241)	45 000 (310)	55 000 (379)
3	Longitudinal tensile modulus, min, psi X 10^6 (MPa)	...	1 (6 900)	2 (13 000)	3 (20 700)	4 (27 600)	5 (34 500)	6 (41 400)
4	Pipe stiffness at 5% deflection, min, lbf/in^2 (kPa)	...	100 (689)	150 (1,034)	200 (1,379)	300 (2,069)	400 (2,759)	500 (3,448)

[A]Unspecified.

classification of 233373, 345464 and 444474 respectively is to be used for polyethylene. PEX materials as defined and listed in PPI TR-4 are to be used for crosslinked polyethylene.

5.3.2 *Structural Layer*—The structural layer provides the strength of the composite pipe. The material used shall be modified E-glass fibers as defined in Specification D578. The glass shall be applied in two layers that have opposite wrap directions. The angle of each wrap layer shall be 55 ± 5 degrees from the axial direction, such that the angle between the layers when they cross is 110 ±10 degrees.

NOTE 2—The wrap angle is controlled during manufacture by the process equipment parameters. A successful burst test result verifies the adequacy of the applied wrap angle.

5.3.2.1 The structural layer thickness shall meet the requirements given in Table 3.

5.3.3 *Thermoplastic Outer Layer*—The outer layer shall be constructed from polyethylene or crosslinked polyethylene material complying with Specification D3350 and listed in PPI TR-4. Either PE2708, PE3608 or PE4710, as defined and listed in PPI TR-4, with a Specification D3350 minimum cell classification of 233373, 345464 and 444474 respectively is to be used for polyethylene. PEX materials as defined and listed in PPI TR-4 are to be used for crosslinked polyethylene. The outer layer material shall contain a suitable level of UV inhibitor for the service intended.

5.4 *Rework Material*—Clean rework material only from the first step production of the PE inner layer and not subjected to the second step glass fiber wrapping, generated from the pipe manufacturer's own pipe production, may be used for the inner or outer layers, provided that it can be demonstrated that the composite pipe produced meets all the requirements of this specification.

5.5 *Fittings:*

5.5.1 Fittings shall be of metallic construction complying with material designation AISI 4130 or 4140, Specifications A105/A105M, A106/A106M, A333/A333M or A350/A350M. Specific materials referenced in this section are common materials used in these types of products. Alternate materials proven to provide equal or better performance are acceptable.

5.5.2 All steel flanges shall comply with ANSI B 16.5 requirements.

5.5.3 The fittings may be finished with a protective coating compatible with the intended service.

6. Physical Requirements

6.1 *Workmanship*—The pipe shall be free of all defects including indentations, bubbles, pinholes, and foreign inclusions, which, due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, and other physical properties. The bore of the pipe shall be smooth and uniform. All pipe ends shall be cut at right angles to the axis of the pipe and any sharp edges removed.

6.2 *Dimensions and Tolerances*—The inside diameter, outside diameter, wall thickness and tolerances of pipe meeting this specification shall conform to the requirements of Table 4, when determined in accordance with 8.3.

6.3 *Pipe Requirements:*

6.3.1 *Pressure Design Basis (PDB)*—Pipe meeting this specification shall be categorized by a long - term static or cyclic pressure design basis as shown in Table 1. A pipe from each Design Basis Category shall be tested in accordance with 8.4 or 8.5, as applicable. The pressure design basis of other pipe sizes with the same pressure design basis having the same materials, reinforcement configuration, reinforcement wrap

TABLE 3 Structural Layer Thickness, in. (mm)

Nominal Pipe Size	PDB Psig (MPa)	Structural Layer Thickness	Tolerance of Layer Thickness
2	800 (5.52)	0.025 (0.64)	± 0.002 (0.04)
2	2,000 (13.8)	0.059 (1.50)	± 0.004 (0.09)
2	4,000 (27.6)	0.120 (3.05)	± 0.007 (0.18)
3	800 (5.52)	0.035 (0.89)	±0.002 (0.05)
3	2,000 (13.8)	0.085 (2.16)	± 0.005 (0.13)
3	4,000 (27.6)	0.165 (4.19)	± 0.01 (0.25)
4	800 (5.52)	0.046 (1.17)	± 0.003 (0.07)
4	2,000 (13.8)	0.109 (2.77)	± 0.007 (0.17)
4	4,000 (27.6)	0.220 (5.59)	± 0.013 (0.34)
6	800 (5.52)	0.058 (1.47)	± 0.003 (0.09)
6	2,000 (13.8)	0.140 (3.56)	±- 0.008 (0.21)
6	4,000 (27.6)	0.280 (7.11)	± 0.017 (0.43)

TABLE 4 Dimensions and Tolerances, in. (mm)[A]

Nominal Pipe Size	PDB (psig)	Inside Diameter of Inner Layer	Tolerance	Outside Diameter of Inner Layer	Tolerance	Outside Diameter Of Outer Layer	Tolerance	Wall Thickness	Tolerance
2	800	2.120	±0.020	2.390	±0.020	2.700	±0.030	0.290	±0.050
		(53.8)	(±0.51)	(60.7)	(±0.51)	(68.6)	(±0.76)	(7.37)	(±1.27)
2	2 000	2.120	±0.020	2.390	±0.020	2.730	±0.030	0.305	±0.050
		(53.8)	(±0.51)	(60.7)	(±0.51)	(69.3)	(±0.76)	(7.75)	(±1.27)
2	4 000	2.120	±0.020	2.390	±0.020	2.860	±0.030	0.370	±0.050
		(53.8)	(±0.51)	(60.7)	(±0.51)	(72.6)	(±0.76)	(9.40)	(±1.27)
3	800	3.020	±0.025	3. 400	±0.030	3.740	±0.030	0.360	±0.050
		(76.7)	(±0.64)	(86.4)	(±0.76)	(95.0)	(±0.76)	(9.14)	(±1.27)
3	2 000	3.020	±0.025	3. 400	±0.030	3.800	±0.030	0.390	±0.050
		(76.7)	(±0.64)	(86.4)	(±0.76)	(96.5)	(±0.76)	(9.91)	(±1.27)
3	4 000	3.020	±0.025	3.400	±0.030	3.960	±0.030	0.470	±0.050
		(76.7)	(±0.64)	(86.4)	(±0.76)	(100.6)	(±0.76)	(11.94)	(±1.27)
4	800	3.900	±0.030	4.410	±0.040	4.790	±0.030	0.445	±0.050
		(99.1)	(±0.76)	(112.0)	(±1.02)	(121.7)	(±0.76)	(11.30)	(±1.27)
4	2 000	3.900	±0.030	4.410	±0.040	4.890	±0.030	0.495	±0.050
		(99.1)	(±0.76)	(112.0)	(±1.02)	(124.2)	(±0.76)	(12.57)	(±1.27)
4	4 000	3.900	±0.030	4.410	±0.040	5.170	±0.030	0.635	±0.050
		(99.1)	(±0.76)	(112.0)	(±1.02)	(131.3)	(±0.76)	(16.13)	(±1.27)
6	800	5.000	±0.035	5.770	±0.050	6.250	±0.030	0.625	±0.050
		(127.0)	(±0.89)	(146.6)	(±1.27)	(158.8)	(±0.76)	(15.88)	(±1.27)
6	2 000	5.000	±0.035	5.770	±0.050	6.430	±0.030	0.715	±0.050
		(127.0)	(±0.89)	(146.6)	(±1.27)	(163.3)	(±0.76)	(18.16)	(±1.27)
6	4 000	5.000	±0.035	5.770	±0.050	6.800	±0.030	0.900	±0.050
		(127.0)	(±0.89)	(146.6)	(±1.27)	(172.7)	(±0.76)	(22.86)	(±1.27)

[A]Diameters and PDBs other than listed in Table 4 shall be permitted by agreement between the manufacturer and the purchaser.

angles, and reinforcement stress levels but different pipe diameter as pipe previously tested in accordance with 8.4 or 8.5 shall be confirmed through testing in accordance with 8.9. Pipe used in static pressure applications shall also meet the cyclic capability requirement described in 8.16.

NOTE 3—Since the ratio of inside diameter to structural layer thickness is constant within a PDB rating, only one pipe diameter per PDB rating needs complete Specification D2992 testing. The other pipe diameters within a PDB rating shall be confirmed by testing per Specification D2992 Section 12. See Appendix X2 for inside diameter/structural layer thickness ratios.

NOTE 4—Cyclic pressure applications are known to be more severe than static pressure applications. It is acceptable to allow cyclically rated pipes to be used in static service.

6.3.2 *Cell Classification*—The pipe shall meet the applicable cell classification requirements for short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus and pipe stiffness as described in Table 2 when tested in accordance with 8.6 through 8.8.

6.3.3 *Pipe Re-categorization*—Any significant changes in the design, materials or manufacturing process of the pipe will require re-categorizing according to 6.3.1 and 6.3.2. These changes include, but are not limited to, a change in the reinforcement type, composition, diameter or layer thickness; a change in the thermoplastic material type, composition or thickness.

6.3.4 *Bending Requirements*—The pipe shall meet the bending requirements specified in the tests as described in 8.10 through 8.12. The minimum bend radius of pipes in service shall not be less than 20 times the pipe outside diameter, for example, for NPS 4 PDB 4000 pipe, the minimum bend radius shall not be less than 103.4 in.

NOTE 5—The purchaser should consult the manufacturer for the proper type of pipe to be used under the installation and operating conditions, with respect to temperature, conveyed fluid, pressure, etc., that will exist for the project in which the pipe is to be used.

6.4 *Fittings Requirements*—The fittings shall seal on the inside diameter of the pipe inner layer. The fittings performance shall be demonstrated by the pressure tests in section 8 where all test specimens shall include fittings assembled as per the manufacturer recommendations for field installation.

6.5 *Joint Requirements:*

6.5.1 *Leak Test*—The fitting to pipe seal shall be leak free when leak tested in accordance with 8.13.

6.5.2 *Tensile Pull Test Requirements*—The fitting to pipe connection shall be proven to be resistant to the manufacturer maximum recommended pull force for the product. No leakage is permitted when tested in accordance with 8.14.

6.5.3 *Temperature Cycling*—The fitting to pipe seal shall be leak-free after ten temperature cycles when tested in accordance with 8.15.

6.5.4 *Elevated Temperature Test*—The fitting to pipe connection shall not leak when tested as per 8.17.

7. Sampling

7.1 At least one sample of pipe shall be taken at random on a weekly basis or on each production run, whichever is the most frequent, to determine conformance of the material to the short - term pressure rupture requirements as shown in Table 2. The rate of sampling for the other tests listed shall be in accordance with accepted statistical practice or as agreed upon between the purchaser and the seller.

7.2 For individual orders, only those additional tests and number of tests specifically agreed upon between the purchaser and the seller need to be conducted.