Designation: D 2996 – 01

An American National Standard

Standard Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[1]

This standard is issued under the fixed designation D 2996; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope *

1.1 This specification[2] covers machine-made reinforced thermosetting resin pressure pipe (RTRP) manufactured by the filament winding process up to 24 in. nominal size. Included are a classification system and requirements for materials, mechanical properties, dimensions, performance, methods of test, and marking.

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

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—The term "fiberglass pipe" as described in Section 3 of this specification applies to both reinforced thermosetting resin pipe (RTRP) and reinforced polymer mortar pipe (RPMP). This specification covers only reinforced thermosetting resin pipe (RTRP).

NOTE 2—This specification is applicable to RTRP where the ratio of outside diameter to wall thickness is 10:1 or more.

NOTE 3—There is no similar or equivalent ISO Standard.

NOTE 4—For the purposes of this standard, polymer does not include natural polymers.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 638 Test Method for Tensile Properties of Plastics[2]

D 883 Terminology Relating to Plastics[2,3]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2,3]

D 2105 Test Method for Longitudinal Tensile Properties of" Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[3]

D 2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe[3]

D 2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[3]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for" Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[3]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminologies D 883 and F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for reinforced thermosetting resin pipe is RTRP.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coating*—a resin layer, with or without filler or reinforcement, or both, applied to the exterior surface of the pipe structural wall.

3.2.2 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.3 *filament winding*—a process used to manufacture tubular goods by winding continuous fibrous glass strand roving, or roving tape, saturated with liquid resin or preimpregnated with partially cured resin (subsequent heating may be required to polymerize the resin system) onto the outside of a mandrel in a predetermined pattern under controlled tension;

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[2] This specification was revised to include an ISO equivalency statement and a section on keywords.

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

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

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

the inside diameter (ID) of the pipe is fixed by the mandrel outside diameter and the outside diameter (OD) of the pipe is determined by the amount of material that is wound on the mandrel.

3.2.4 *liner*—the inner portion of the wall at least 0.005 in. (0.13 mm) in thickness, as determined in 8.3.2, which does not contribute to the strength in the determination of the hydrostatic design basis.

3.2.5 *reinforced polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

3.2.7 *reinforced wall thickness*—the total wall thickness minus the liner or exterior coating thickness, or both.

4. Classification

4.1 *General*—Pipe meeting this specification is classified by type, grade, class, and hydrostatic design basis in accordance with Classification D 2310 and by a secondary cell classification system that defines the basic mechanical properties of the pipe. These types, grades, classes, hydrostatic design basis categories, and cell classification designations are as follows:

4.1.1 *Types:—Type 1*

Filament wound.

4.1.2 *Grades:—Grade 1*

Glass fiber reinforced epoxy resin pipe.

Grade 2—Glass fiber reinforced polyester resin pipe.

Grade 7—Glass fiber reinforced furan resin pipe.

4.1.3 *Classes:—Class A*

No liner.

Class B—Polyester resin liner (nonreinforced).

Class C—Epoxy resin liner (nonreinforced).

Class E—Polyester resin liner (reinforced).

Class F—Epoxy resin liner (reinforced).

Class H—Thermoplastic resin liner (specify).

Class I—Furan resin liner (reinforced).

4.1.4 *Hydrostatic Design Basis*—Two methods of classifying the hydrostatic 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 as shown in Table 1. Appendix X1 explains how these design basis categories are to be used.

4.1.4.1 For pipe subjected to axial or end loads, the effect of these loads shall be represented in the HDB testing. In the designation code, the numeral 1 shall immediately follow the HDB letter class if free-end type closures were used and the numeral 2 shall immediately follow the HDB letter class if restrained-end type closures were used to establish the HDB.

TABLE 1 Hydrostatic Design Basis Categories

Cyclic Test Method		Static Test Method	
Designation	Hoop Stress, psi (MPa)	Designation	Hoop Stress, psi (MPa)
A	2 500 (17.2)	Q	5 000 (34.5)
B	3 150 (21.7)	R	6 300 (43.4)
C	4 000 (27.6)	S	8 000 (55.2)
D	5 000 (34.5)	T	10 000 (68.9)
E	6 300 (43.4)	U	12 500 (86.2)
F	8 000 (55.2)	W	16 000 (110)
G	10 000 (68.9)	X	20 000 (138)
H	12 500 (86.2)	Y	25 000 (172)
		Z	31 500 (217)

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

NOTE 5—All possible combinations covered by the above classification system may not be commercially available.

4.1.6 *Designation Code*—The pipe designation code shall consist of the abbreviation RTRP, followed by the type and grade in Arabic numerals, the class and static or cyclic HDB level in capital letters, the type of end closure used, and four Arabic numbers identifying, respectively, the cell classification designations of the short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus, and apparent stiffness of the pipe.

Example: RTRP-11FA1-1334. Such a designation would describe a filament-wound, glass-fiber reinforced, epoxy pipe having a reinforced epoxy liner; a cyclic pressure strength exceeding 2500 psi (17.2 MPa) using free-end closures; a short-term rupture strength exceeding 10 000 psi (68.9 MPa); a longitudinal tensile strength exceeding 25 000 psi (172 MPa); a longitudinal tensile modulus exceeding 3×10^6 psi (20.7×10^3MPa); and an apparent stiffness factor exceeding 1500 $in.^3 \cdot lbf/in.^2$ (170 $mm^3 \cdot kPa$).

5. Materials and Manufacture

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

6. Physical Requirements

6.1 *Workmanship*—The pipe shall be free of all defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas 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 pipe shall be round and straight and 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*:

6.2.1 *Inside and Outside Diameter*—The inside and outside diameter and tolerances of pipe meeting these specifications shall conform to the requirements in one of the Tables 3-6, when determined in accordance with 8.3.1.

6.2.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not at any point be less than 87.5 % of the nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 8.3.1.

6.3 *Performance*—Pipe meeting this specification shall be categorized by a long-term static or cyclic hydrostatic design basis as shown in Table 1 when tested in accordance with 8.4 or 8.5. Additionally, the pipe shall meet the applicable cell limit

TABLE 2 Physical Property Requirements

Designation Order Number	Mechanical Property	0[A]	1	2	3	4	5	6
1	Short-term rupture strength hoop tensile stress, min, psi[B]	...	10 000	30 000	40 000	50 000	60 000	70 000
	(MPa)	...	(68.9)	(207)	(276)	(345)	(414)	(483)
2	Longitudinal tensile strength min, psi	...	8 000	15 000	25 000	35 000	45 000	55 000
	(MPa)	...	(55.2)	(103)	(172)	(241)	(310)	(379)
3	Longitudinal tensile modulus, min, psi × 10^6	...	1	2	3	4	5	6
	(MPa)	...	(6 900)	(13 000)	(20 700)	(27 600)	(34 500)	(41 400)
4	Apparent stiffness factor at 5 % deflection, min, $in.^3 \cdot lbf/in.^2$	...	40	200	1000	1500	2000	2500
	$(mm^3 \cdot kPa)$	...	(4.5)	(22.6)	(113)	(170)	(226)	(282)

[A] Unspecified.
[B] Type of end closure used, that is, free or restrained should be indicated on certification.

TABLE 3 Dimensions and Tolerances for Outside Diameter (OD) Series Pipe with Steel-Pipe-Equivalent (Iron Pipe Size)

Nominal Pipe Size, in.	in.	(mm)
1	1.315 + 0.060 −0.016	33.40 + 1.52 −0.41
1½	1.900 + 0.060 −0.018	48.26 + 1.52 −0.46
2	2.375 + 0.060 −0.018	60.32 + 1.52 −0.46
2½	2.875 + 0.060 −0.018	73.02 + 1.52 −0.46
3	3.500 + 0.060 −0.018	88.90 + 1.52 −0.46
4	4.500 + 0.060 −0.018	114.30 + 1.52 −0.46
6	6.625 + 0.066 −0.028	168.28 + 1.68 −0.64
8	8.625 + 0.086 −0.040	219.08 + 2.18 −1.02
10	10.750 + 0.108 −0.048	273.05 + 2.74 −1.22
12	12.750 + 0.128 −0.056	323.85 + 3.25 −1.42
14	14.000 + 0.145 −0.064	355.60 + 3.68 −1.63
16	16.000 + 0.165 −0.074	406.40 + 4.19 −1.88

[A] Outside diameters other than listed in Tables 3 to 6 shall be permitted by agreement between the manufacturer and the purchaser.

TABLE 4 Dimensions and Tolerances for Inside Diameter (ID) Series Pipe

Nominal Pipe Size, in.	in.	mm
1	1.00 ± 0.06	25.4 ± 1.52
1½	1.500± 0.06	38.1 ± 1.52
2	2.000 ± 0.06	50.8 ± 1.52
2½	2.500± 0.06	63.5 ± 1.52
3	3.000 ± 0.12	76.2 ± 3.05
4	4.000 ± 0.12	101.6 ± 3.05
6	6.000 ± 0.25	152.4 ± 6.35
8	8.000 ± 0.25	203.2 ± 6.35
10	10.000 ± 0.25	254.0 ± 6.35
12	12.000 ± 0.25	304.8 ± 6.35
14	14.000 ± 0.25	355.6 ± 6.35
15	15.000 ± 0.25	381.0 ± 6.35
16	16.000 ± 0.25	406.4 ± 6.35
18	18.000 ± 0.25	457.2 ± 6.35
20	20.000 ± 0.25	508.0 ± 6.35
24	24.000 ± 0.25	609.6 ± 6.35

TABLE 5 Dimensions for Outside Diameter (OD) Series Pipe with Cast-Iron-Pipe-Equivalent

Nominal Pipe Size, in.	in.	mm
2	2.50 + 0.05 −0.05	63.50 + 1.27 −1.27
3	3.96 + 0.06 −0.06	100.58 + 1.52 −1.52
4	4.80 + 0.06 −0.06	121.92 + 1.52 −1.52
6	6.90 + 0.06 −0.06	175.26 + 1.52 −1.52
8	9.05 + 0.06 −0.06	229.87 + 1.52 −1.52
10	11.10 + 0.06 −0.06	281.94 + 1.52 −1.52
12	13.20 + 0.06 −0.06	335.28 + 1.52 −1.52
14	15.30 + 0.05 −0.08	388.62 + 1.27 −2.03
16	17.40 + 0.05 −0.08	441.96 + 1.27 −2.03

requirements for short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus, and apparent stiffness factor as described in Table 2 when tested in accordance with 8.6 through 8.8.

6.3.1 Any significant changes in the original pipe categorized in 6.3, with respect to materials or manufacturing process, will require recategorizing according to 6.3. These changes include, but are not limited to: a change in reinforcement type, composition, or binder; a change in resin type, composition, or cure; or change in linear composition, thickness, or cure.

NOTE 6—The purchaser should consult the manufacturer for the proper class, type, and grade 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.

7. Sampling

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

7.2 For individual orders, only those additional tests and

TABLE 6 Dimensions for Inside Diameter (ID) Series Pipe with Iron Pipe Size Equivalent

Nominal Pipe Size, in.	in.	mm
2	2.25 + 0.05 −0.05	57.15 + 1.27 −1.27
3	3.34 + 0.06 −0.06	84.84 + 1.52 −1.52
4	4.37 + 0.06 −0.06	111.00 + 1.52 −1.52
6	6.43 + 0.06 −0.06	163.32 + 1.52 −1.52
8	8.39 + 0.06 −0.06	213.11 + 1.52 −1.52
10	10.43 + 0.06 −0.06	264.92 + 1.52 −1.52
12	12.38 + 0.06 −0.06	314.45 + 1.52 −1.52
14	13.60 + 0.05 −0.08	345.44 + 1.27 −2.03
16	15.40 + 0.05 −0.08	391.16 + 1.27 −2.03

number of tests specifically agreed upon between the purchaser and the seller need to be conducted.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 48 h prior to test, in accordance with Procedure A of Methods D 618, for those tests where conditioning is required, and in all cases of disagreement.

8.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test method or in this specification.

8.3 *Dimensions and Tolerances*:

8.3.1 *Wall Thickness and Diameter*—Determine in accordance with Practice D 3567.

8.3.2 *Liner Thickness*—If the test specimens contain a liner, determine the average liner thickness in accordance with Practice D 3567.

8.4 *Long-Term Cyclic Hydrostatic Strength*—Determine in accordance with Procedure A of Method D 2992, following Test Method D 2143.

8.5 *Long-Term Static Hydrostatic Strength*—Determine in accordance with Procedure B of Method D 2992, following Test Method D 1598.

8.6 *Short-Term Hydrostatic Failure Strength*—Determine in accordance with Test Method D 1599.

8.7 *Longitudinal Tensile Properties*— Determine in accordance with Test Methods D 2105 or D 638.

8.8 *Stiffness Factor*—Determine in accordance with Test Method D 2412. The reported stiffness shall be based on 5 % deflection.

9. Certification

9.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material. This shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification. Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

9.2 When original identity cannot be established, certification can only be based upon the sampling procedure provided by the applicable specification.

10. Product Marking

10.1 Each piece of pipe shall be marked at least once per section. Each piece of pipe shall be marked with the following information in such a manner that it remains legible under normal handling and installation practices:

10.1.1 Nominal pipe size (for example, 2 in.).

10.1.2 Identification of reinforced thermosetting resin pipe in accordance with the designation code given in Section 4.

10.1.3 ASTM D 2996 with which the pipe complies.

10.1.4 Manufacturer's name (or trademark).

11. Keywords

11.1 filament-wound FRP pipe; mechanical properties; physical properties; pressure rating; tolerances; wall thickness

APPENDIX

(Nonmandatory Information)

X1. HYDROSTATIC DESIGN BASIS, CATEGORIES, SERVICE FACTORS, AND PRESSURE RATINGS

X1.1 Hydrostatic Design Basis

X1.1.1 The hydrostatic design basis for reinforced thermosetting resin pipe is the estimated long-term hydrostatic strength obtained in accordance with Method D 2992. In Method D 2992 either Procedure A, using data obtained in accordance with Test Method D 2143, or Procedure B, using data obtained in accordance with Test Method D 1598, is used to determine the estimated long-term hydrostatic strength. This strength in the wall of the pipe is equal to the circumferential stress due to internal hydrostatic pressure that will fail the pipe when extrapolated to 150 × 10^6 pressure cycles (Procedure A) or to 100 000 h under continuously applied pressure (Procedure B).

X1.2 Hydrostatic Design Basis Categories

X1.2.1 The hydrostatic design basis category is obtained from Table X1.1 or Table X1.2 using the estimated long-term

TABLE X1.1 Hydrostatic Design Basis Categories by Procedure A

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
2 500 (17.2)	2 400 to 3 010 (16.5 to 20.8)
3 150 (21.7)	3 020 to 3 020 (20.8 to 26.3)
4 000 (27.6)	3 830 to 4 790 (26.4 to 33.0)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)

TABLE X1.2 Hydrostatic Design Basis Categories by Procedure B

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.1)
12 500 (86.2)	12 000 to 15 200 (82.9 to 105)
16 000 (112)	15 300 to 18 900 (105 to 130)
20 000 (138)	19 000 to 23 000 (131 to 159)
25 000 (173)	24 000 to 29 000 (165 to 200)
31 500 (217)	30 000 to 38 000 (207 to 262)

hydrostatic strength as the calculated value.

X1.3 Service (Design) Factor

X1.3.1 The service (design) factor is a number equal to 1.00 or less which takes into consideration all the variables and degree of safety involved in a reinforced thermosetting resin pressure piping installation and is selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables (specifically, normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures of this method). The second group considers the application or use (specifically, installation, environment, temperature hazard involved, life expectancy desired, and the degree of reliability selected).

NOTE X1.1—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after fully evaluating the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

X1.4 Hydrostatic Design Stress

X1.4.1 The hydrostatic design stress is the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure will not occur. It is obtained by multiplying the hydrostatic design basis as determined by Procedure A or Procedure B by the service (design) factor.

X1.5 Pressure Rating

X1.5.1 The pressure rating is the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

X1.5.2 The pressure rating for each diameter and wall thickness of pipe and fitting is calculated from hydrostatic design stress for the specific pipe by means of the following formula:

$$S = P\,(D - t)/2t$$

where:

S = hydrostatic design stress, psi (MPa),
P = pressure rating, psi (MPa),
D = average outside diameter, in. (mm), and
t = minimum reinforced wall thickness, in. (mm).

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue D 2996 – 00 that may impact the use of this standard.

(*1*) Changed acronym, RPMP, from reinforced *plastic* mortar pipe to reinforced *polymer* mortar pipe.