Designation: D 3754 – 04

An American National Standard

Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe[1]

This standard is issued under the fixed designation D 3754; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers machine-made fiberglass pipe, 8 in. (200 mm) through 144 in. (3700 mm), for use in pressure systems for conveying sanitary sewage, storm water, and many industrial wastes, and corrosive fluids. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes. This standard is suited primarily for pipes to be installed in buried applications, although it may be used to the extent applicable for other installations such as, but not limited to, jacking, tunnel lining and sliplining and rehabilitation of existing pipelines. Pipe covered by this specification is intended to operate at internal gage pressures of 250 psi (1.72 MPa) or less.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

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

NOTE 2—There is no similar or equivalent ISO standard.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service

D 638 Test Method for Tensile Properties of Plastics

D 695 Test Method for Compressive Properties of Rigid Plastics

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D 883 Terminology Relating to Plastics

D 1600 Terminology for Abbreviated Terms Relating to Plastics

D 2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method

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

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins

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

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

D 3681 Test Method for Chemical Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition

D 3892 Practice for Packaging/Packing of Plastics

D 4161 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals

F 412 Terminology Relating to Plastic Piping Systems

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

2.2 *ISO Standard:*

ISO 1172 Textile Glass Reinforced Plastics—Determination of Loss on Ignition[3]

2.3 *AWWA Standard:*

AWWA C-950 Glass-Fiber Reinforced Thermosetting Resin Pressure Pipe[4]

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

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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] Available from American National Standards Institute (ANSI), 11 West 42nd Street, 13th Floor, New York, NY 10036.

[4] Available from the American Water Works Association, 6666 West Quincey Ave., Denver, CO 80235.

3. Terminology

3.1 *Definitions:*

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *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.

3.2.2 *flexible joint*—a joint that is capable of axial displacement or angular rotation, or both.

3.2.3 *industrial pipe*—pipe designed for internal, or external environments, or both, commonly encountered in industrial piping systems used for many process solutions or effluents.

3.2.4 *liner*—a resin layer, with or without filler or reinforcement, or both, forming the interior surface of the pipe.

3.2.5 *qualification test*—one or more tests used to prove the design of a product. Not a routine quality control test.

3.2.6 *reinforced polymer mortar pipe*—a fiberglass pipe with aggregate.

3.2.7 *reinforced thermosetting resin pipe*—a fiberglass pipe without aggregate.

3.2.8 *rigid joint*—a joint that is not capable of axial displacement or angular rotation.

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

4. Classification

4.1 *General*—This specification covers fiberglass sewer and industrial pressure pipe defined by raw materials in the structural wall (type) and liner, surface layer material (grade), operating pressure (class), and pipe stiffness. Table 1 lists the types, liners, grades, classes, and stiffnesses that are covered.

NOTE 3—All possible combinations of types, liners, grades, classes, and stiffness may not be commercially available. Additional types, liners, grades, and stiffnesses may be added as they become commercially available. The purchaser should determine for himself or consult with the manufacturer for the proper class, type, liner, grade, and stiffness of pipe to be used under the installation and operating conditions that will exist for the project in which the pipe is to be used.

4.2 *Designation Requirements*—The pipe materials designation code shall consist of the standard designation, ASTM D 3754, followed by type, liner, and grade in arabic numerals, class by the letter C with two or three arabic numerals, and pipe stiffness by a capital letter. Table 1 presents a summary of the designation requirements. Thus a complete material code shall consist of ASTM D 3754, three numerals, C...and two or three numerals, and a capital letter.

NOTE 4—Examples of the designation codes are as follows: (*1*) ASTM D 3754-1-1-3-C50-A for glass-fiber-reinforced aggregate and polyester resin mortar pipe with a reinforced thermoset liner and an unreinforced polyester resin and sand surface layer, for operation at 50 psi (345 kPa), and having a minimum pipe stiffness of 9 psi (62 kPa). (*2*) ASTM D 3754-4-2-6-C200-C for glass-fiber-reinforced epoxy resin pipe with an unreinforced thermoset liner, no surface layer, for operation at 200 psi (1380 kPa) and having a minimum pipe stiffness of 36 psi (248 kPa).

NOTE 5—Although the "Form and Style for ASTM Standards" manual requires that the type classification be roman numerals, it is recognized that few companies have stencil-cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

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.

5.2 *Wall Composition*—The basic structural wall composition shall consist of a thermosetting resin, glass-fiber reinforcement, and, if used, an aggregate filler.

5.2.1 *Resin*—A thermosetting polyester or epoxy resin, with or without filler.

5.2.2 *Aggregate*—A siliceous sand conforming to the requirements of Specification C 33, except that the requirements for gradation shall not apply.

TABLE 1 General Designation Requirements for Fiberglass Pressure Pipe

Designation	Property	Cell Limits[A]								
1	Type	1 glass-fiber-reinforced thermosetting polyester[B] resin mortar (RPMP polyester)[B]	2 glass-fiber-reinforced thermosetting polyester[B] resin (RTRP polyester)[B]	3 glass-fiber-reinforced thermosetting epoxy resin mortar (RPMP epoxy)	4 glass-fiber-reinforced thermosetting epoxy resin (RTRP epoxy)					
2	Liner	1 reinforced thermoset liner	2 non-reinforced thermoset liner	3 thermoplastic liner	4 no liner					
3	Grade	1 Polyester resin surface layer—reinforced[B]	2 polyester[B] resin surface layer—nonreinforced[B]	3 polyester[B] resin and sand surface layer nonreinforced	4 epoxy resin surface layer—reinforced	5 epoxy resin surface layer—nonreinforced	6 No surface layer			
4	Class[C]	C50	C75	C100	C125	C150	C175	C200	C225	C250
5	Pipe Stiffness psi (kPa)	A 9 (62)	B 18 (124)	C 36 (248)	D 72 (496)[ABC]					

[A]The cell-type format provides the means of identification and specification of piping materials. This cell-type format, however, is subject to misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available products. The manufacturer should be consulted.
[B]For the purposes of this standard, polyester includes vinyl ester resin.
[C]Based on operating pressure in psig (numerals).

5.2.3 *Reinforcement*—A commercial grade of glass fiber with a sizing compatible with the resin used.

5.3 *Liner and Surface Layers*—A liner or surface layer, or both, when incorporated into or onto the pipe shall meet the chemical and structural requirements of this specification.

5.4 *Joints*—The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition. A particular type of joint may be restrained or unrestrained and flexible or rigid depending on the specific configuration and design conditions.

5.4.1 *Unrestrained*—Pipe joints capable of withstanding internal pressure but not longitudinal forces.

5.4.1.1 *Coupling or Bell-and-Spigot Gasket Joints*, with a groove either on the spigot or in the bell to retain an elastomeric gasket that shall be the sole element of the joint to provide watertightness. For typical joint details see Fig. 1.

5.4.1.2 *Mechanical Coupling Joint*, with elsastomeric seals.

5.4.1.3 *Butt Joint*, with laminated overlay

5.4.1.4 *Flanged Joint*, both integral and loose ring.

5.4.2 *Restrained*—Pipe joints capable of withstanding internal pressure and longitudinal tensile loads.

5.4.2.1 Joints similar to those in 5.4.1.1 with supplemental restraining elements.

5.4.2.2 *Butt Joint*, with laminated overlay.

5.4.2.3 *Bell-and-Spigot*, with laminated overlay.

5.4.2.4 *Bell-and-Spigot*, adhesive-bonded-joint: Three types of adhesive-bonded joints are premitted by this standard as follows:

5.4.2.4.1 *Tapered bell-and-spigot*, an adhesive joint that is manufactured with a tapered socket for use in conjunction with a tapered spigot and a suitable adhesive.

5.4.2.4.2 *Straight bell-and-spigot*, an adhesive joint that is manufactured with an untapered socket for use in conjunction with an untapered spigot and a suitable adhesive.

5.4.2.4.3 *Tapered bell and straight spigot*, an adhesive joint that is manufactured with a tapered socket for use with an untapered spigot and a suitable adhesive.

5.4.2.5 *Flanged Joint*, both integral and loose ring.

5.4.2.6 *Threaded Joints*.

5.4.2.7 *Mechanical Coupling*, an elastomeric sealed coupling with supplemental restraining elements.

NOTE 6—Other types of joints may be added as they become commercially available.

NOTE 7—Restrained joints typically increase service loads on the pipe to greater than those experienced with unrestrained joints. The purchaser is cautioned to take into consideration all conditions that may be encountered in the anticipated service and to consult the manufacturer regarding the suitability of a particular type and class of pipe for service with restrained joint systems.

5.5 *Gaskets*—Elastomeric gaskets, when used with this pipe, shall conform to the requirements of Specification F 477, except that composition of the elastomer shall be as agreed upon between the purchaser and the supplier for the particular exposure to oily or aggressive-chemical environments.

6. Requirements

6.1 *Workmanship*:

6.1.1 Each pipe shall be free from all defects including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that 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, density, and other physical properties.

6.1.2 The inside surface of each pipe shall be free of bulges, dents, ridges, or other defects that result in a variation of inside diameter of more than ⅛ in. (3.2 mm) from that obtained on adjacent unaffected portions of the surface. No glass-fiber reinforcement shall penetrate the interior surface of the pipe wall.

6.1.3 Joint sealing surfaces shall be free of dents, gouges, or other surface irregularities that will affect the integrity of the joints.

6.2 *Dimensions*:

6.2.1 *Pipe Diameters*—The pipe shall be supplied in the nominal diameters shown in Table 2 or Table 3. The pipe diameter tolerances shall be as shown in Table 2 or Table 3, when measured in accordance with 8.1.1.

6.2.2 *Lengths*—The pipe shall be supplied in nominal lengths of 10, 20, 30, 40, and 60 ft (3.05, 6.10, 9.15, 12.19, and 18.29 m). The actual laying length shall be the nominal length ±2 in. (±51 mm), when measured in accordance with 8.1.2. At least 90 % of the total footage of any one size and class, excluding special-order lengths, shall be furnished in the nominal lengths specified by the purchaser. Random lengths, if furnished, shall not vary from the nominal lengths by more than 5 ft (1.53 m), or 25 %, whichever is less.

6.2.3 *Wall Thickness*—The average wall thickness of the pipe shall not be less than the nominal wall thickness published in the manufacturer's literature current at the time of purchase, and the minimum wall thickness at any point shall not be less than 87.5 % of the nominal wall thickness when measured in accordance with 8.1.3.

6.2.4 *Squareness of Pipe Ends*—All points around each end of a pipe unit shall fall within ±¼ in. (6.4 mm) or ±0.5 % of the nominal diameter of the pipe, whichever is greater, to a plane perpendicular to the longitudinal axis of the pipe, when measured in accordance with 8.1.4.

6.3 *Chemical Requirements*:

6.3.1 *Sanitary Sewer Service* :

6.3.1.1 *Long-Term*—Pipe specimens, when tested in accordance with 8.2.1 shall be capable of being deflected, without failure, at the 50 year strain level given in Table 4 when exposed to 1.0 *N* sulfuric acid.

NOTE 8—See Appendix X1 for derivation of the minimum sanitary sewer pipe chemical requirements given in Table 4.

NOTE 9—The calculations in Table 4 and Appendix X1 assume that the neutral axis is at the pipe wall midpoint. For pipe wall constructions that

FIG. 1 Typical Joints

TABLE 2 Nominal Inside Diameters (ID) and Tolerances Inside Diameter Control Pipe

Nominal Diameter,[A] in.	Tolerances, in.	Nominal Metric Diameter,[B] mm	ID Range,[B] mm Minimum	ID Range,[B] mm Maximum	Tolerance[B] on Declared ID, mm
8	±0.25	200	196	204	±1.5
10	±0.25	250	246	255	±1.5
12	±0.25	300	296	306	±1.8
14	±0.25	400	396	408	±2.4
15	±0.25	500	496	510	±3.0
16	±0.25	600	595	612	±3.6
18	±0.25	700	695	714	±4.2
20	±0.25	800	795	816	±4.2
21	±0.25	900	895	918	±4.2
24	±0.25	1000	995	1020	±5.0
27	±0.27	1200	1195	1220	±5.0
30	±0.30	1400	1395	1420	±5.0
33	±0.33	1600	1595	1620	±5.0
36	±0.36	1800	1795	1820	±5.0
39	±0.39	2000	1995	2020	±5.0
42	±0.42	(2200)	2195	2220	±6.0
45	±0.45	2400	2395	2420	±6.0
48	±0.48	(2600)	2595	2620	±6.0
51	±0.51	2800	2795	2820	±6.0
54	±0.54	(3000)	2995	3020	±6.0
60	±0.60	3200	3195	3220	±7.0
66	±0.66	(3400)	3395	3420	±7.0
72	±0.72	3600	3595	3620	±7.0
78	±0.78	(3800)	3795	3820	±7.0
84	±0.84	4000	3995	4020	±7.0
90	±0.90	. . .	. . .	. . .	. . .
96	±0.96	. . .	. . .	. . .	. . .
102	±1.00	. . .	. . .	. . .	. . .
108	±1.00	. . .	. . .	. . .	. . .
114	±1.00	. . .	. . .	. . .	. . .
120	±1.00	. . .	. . .	. . .	. . .
132	±1.00	. . .	. . .	. . .	. . .
144	±1.00	. . .	. . .	. . .	. . .

[A]Inside diameters other than those shown shall be permitted by agreement between purchaser and supplier.
[B]Values are taken from International Standards Organization documents. Parentheses indicate non-preferred diameters.

produce an altered neutral axis position, it is necessary to evaluate results and establish requirements substituting 2*y* for *t*. (*y* is the maximum distance from the neutral axis to the pipe surface.)

6.3.1.2 *Control Requirements*—Test pipe specimens periodically in accordance with 8.2.1.3, following the procedure of 8.2.1.4, or alternatively, the procedure of 8.2.1.5.

6.3.1.3 When the procedure of 8.2.1.4 is used, the following three criteria must be met: a) the average failure time at each strain level must fall at or above the lower 95 % confidence limit of the originally determined regression line, b) no specimen-failure times may be sooner than the lower 95 % prediction limit of the originally determined regression line, and c) one-third or more of the specimen failure times must be on or above the originally determined regression line.

NOTE 10—Determine the lower 95 % confidence limit and the lower 95 % prediction limit in accordance with to Annex A2.

6.3.1.4 When the alternative method of 8.2.1.5 is used, failure shall not occur in any specimen.

6.3.2 *Industrial Service*—The resin component of the liner or of the surface layer, or both, shall be a commercial-grade corrosion-resistant thermoset that has either been evaluated in a laminate by test, in accordance with 8.2.2, or that has been determined by previous documented service to be acceptable for the service conditions. Where service conditions have not been evaluated, a suitable resin may also be selected by agreement between the manufacturer and purchaser.

NOTE 11—The results obtained by this test shall serve as a guide only in the selection of a pipe material for a specific service application. The purchaser is cautioned to evaluate all of the various factors that may enter into the serviceability of a pipe material when subjected to chemical environment, including chemical resistance in the strained condition.

6.4 *Soundness*—Unless otherwise agreed upon between purchaser and supplier, test each length of pipe up to 54 in. (1370 mm) diameter hydrostatically without leakage or cracking, at the internal hydrostatic proof pressures specified for the applicable class in Table 5 when tested in accordance with 8.3. For sizes over 54 in., the frequency of hydrostatic leak tests shall be as agreed upon by purchaser and supplier.

6.5 *Hydrostatic Design Basis*:

6.5.1 *Long-Term Hydrostatic Pressure*—The pressure classes shall be based on long-term hydrostatic pressure data obtained in accordance with 8.4 and categorized in accordance with Table 6. Pressure classes are based on extrapolated strengths at 50 years. For pipe subjected to longitudinal loads or circumferential bending, the effect of these conditions on the hydrostatic design pressure classification of the pipe must be considered.

6.5.2 *Control Requirements*—Test pipe specimens periodically in accordance with the reconfirmation procedures described in Practice D 2992.

NOTE 12—Hydrostatic design basis (HDB—extrapolated value at 50 years) determined in accordance with Procedure A of Practice D 2992,

TABLE 3 Nominal Outside Diameters (OD) and Tolerances

Nominal Pipe Size, in.	Steel Pipe Equivalent (IPS) OD's, in.	Tolerance, in.	Cast Iron Pipe Equivalent OD's, in.	Tolerance, in.
8	8.625	+0.086	9.05	
		−0.040		
10	10.750	+0.108	11.10	
		−0.048		±0.06
12	12.750	+0.128	13.20	
		−0.056		
14	14.000	+0.140	15.30	
		−0.062		
16	16.000	+0.160	17.40	
		−0.070		+0.05
18	. . .	. . .	19.50	−0.08
20	. . .	. . .	21.60	
24	. . .	. . .	25.80	
30	. . .	. . .	32.00	
36	. . .	. . .	38.30	
42	. . .	. . .	44.50	+0.08
48	. . .	. . .	50.80	−0.06
54	. . .	. . .	57.56	
60	. . .	. . .	61.61	

Metric Pipe Size, mm	Ductile Iron Pipe Equivalent, mm	Tolerance Upper, mm	Tolerance Lower, mm	International O.D., mm	Tolerance Upper, mm	Tolerance Lower, mm
200	220.0	+1.0	0.0	. . .	. . .	. . .
250	271.8	+1.0	-0.2	. . .	. . .	. . .
300	323.8	+1.0	-0.3	310	+1.0	-1.0
350	375.7	+1.0	-0.3	361	+1.0	-1.2
400	426.6	+1.0	-0.3	412	+1.0	-1.4
450	477.6	+1.0	-0.4	463	+1.0	-1.6
500	529.5	+1.0	-0.4	514	+1.0	-1.8
600	632.5	+1.0	-0.5	616	+1.0	-2.0
				718	+1.0	-2.2
				820	+1.0	-2.4
				924	+1.0	-2.6
				1026	+1.0	-2.6
				. . .	. . .	. . .
				1229	+1.0	-2.6
				1434	+1.0	-2.8
				1638	+1.0	-2.8
				1842	+1.0	-3.0
				2046	+1.0	-3.0
				2250	+1.0	-3.2
				2453	+1.0	-3.4
				2658	+1.0	-3.6
				2861	+1.0	-3.8
				3066	+1.0	-4.0

TABLE 4 Minimum Sanitary Sewer Pipe Chemical Requirements

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Pipe Stiffness, psi (kPa)	Minimum Strain					
	6 min	10 h	100 h	1 000	10 000	50 years
9 (62)	0.97 (t/de)	0.84 (t/d)	0.78 (t/d)	0.73 (t/d)	0.68 (t/d)	0.60 (t/d)
18 (124)	0.85 (t/d)	0.72 (t/d)	0.66 (t/d)	0.61 (t/d)	0.56 (t/d)	0.49 (t/d)
36 (248)	0.71 (t/d)	0.60 (t/d)	0.55 (t/d)	0.51 (t/d)	0.47 (t/d)	0.41 (t/d)
72 (496)	0.56 (t/d)	0.48 (t/d)	0.44 (t/d)	0.41 (t/d)	0.38 (t/d)	0.34 (t/d)

Where: *t* and *d* are the nominal total wall thickness and the mean diameter (inside diameter plus *t*) as determined in accordance with 8.1.

TABLE 5 Hydrostatic-Pressure Test

Class	Hydrostatic Proof Pressure, gage, psi (kPa)
C50	100 (689)
C75	150 (1034)
C100	200 (1379)
C125	250 (1723)
C150	300 (2068)
C175	350 (2412)
C200	400 (2757)
C225	450 (3102)
C250	500 (3445)

TABLE 6 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure. gage, psi (kPa)
C50	90 (621)
C75	135 (931)
C100	180 (1241)
C125	225 (1551)
C150	270 (1862)
C175	315 (2172)
C200	360 (2482)
C225	405 (2792)
C250	450 (3103)

may be substituted for the Procedure B evaluation required by 8.4. It is generally accepted that the Procedure A value multiplied by 3 is equivalent to the Procedure B value.

6.6 *Stiffness*—Each length of pipe shall have sufficient strength to exhibit the minimum pipe stiffness ($F/\Delta y$) specified in Table 7 when tested in accordance with 8.5. At deflection level A per Table 8, there shall be no visible damage in the test specimen evidenced by surface cracks. At deflection level B per Table 8, there shall be no indication of structural damage as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall.

NOTE 13—This is a visual observation (made with the unaided eye) for quality control purposes only, and should not be considered a simulated service test. Table 8 values are based on an in-use long-term deflection limit of 5 % and provide an appropriate uniform safety margin for all pipe stiffnesses. Since the pipe-stiffness values ($F/\Delta y$) shown in Table 7 vary, the percent deflection of the pipe under a given set of installation conditions will not be constant for all pipes. To avoid possible misapplication, take care to analyze all conditions that might affect performance of the installed pipe.

TABLE 7 Minimum Stiffness at 5 % Deflection

Nominal Diameter, in.	Pipe Stiffness, psi (kPa)			
	Designation			
	A	B	C	D
8	. . .	. . .	36 (248)	72 (496)
10	. . .	18 (124)	36 (248)	72 (496)
12 and greater	9 (62)	18 (124)	36 (248)	72 (496)

TABLE 8 Ring Deflection Without Damage or Structural Failure

	Nominal Pipe Stiffness, psi			
	9	18	36	72
Level A	18 %	15 %	12 %	9 %
Level B	30 %	25 %	20 %	15 %

6.6.1 For other pipe stiffness levels, appropriate values for Level A and Level B deflections (Table 8) may be computed as follows:

$$\text{Level A at new PS} = \left(\frac{72}{\text{new PS}}\right)^{0.33}(9) \quad (1)$$

$$\text{Level B at new PS} = \text{new Level A} \div 0.6$$

6.6.2 Since products may have use limits of other than 5 % long-term deflection, Level A and Level B deflections (Table 8) may be proportionally adjusted to maintain equivalent in-use safety margins. For example, a 4 % long-term limiting deflection would result in a 20 % reduction of Level A and Level B deflections, while a 6 % limiting deflection would result in a 20 % increase in Level A and Level B deflection values. However, minimum values for Level A and Level B deflections shall be equivalent to strains of 0.6 and 1.0 % respectively (as computed by Eq X1.1 in Appendix X1).

6.7 *Hoop-Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the hoop-tensile strength shown for each size and class in Table 9 and Table 10, when tested in accordance with 8.6.

6.7.1 *Alternative Requirements*—When agreed upon by the purchaser and the supplier, the minimum hoop tensile strength shall be as determined in accordance with 8.6.1.

6.8 *Joint Tightness*—All joints shall meet the laboratory performance requirements of Specification D 4161. Unrestrained joints shall be tested with a fixed end closure condition and restrained joints shall be tested with a free end closure condition. Rigid joints shall be exempt from angular deflection requirements of D4161. Rigid joints typically include butt

TABLE 9 Minimum Hoop Tensile Strength of Pipe Wall Inch-Pound Units

Nominal Diameter in.	Hoop Tensile Strength, lbf/in. Width								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	800	1 200	1 600	2 000	2 400	2 800	3 200	3 600	4 000
10	1 000	1 500	2 000	2 500	3 000	3 500	4 000	4 500	5 000
12	1 200	1 800	2 400	3 000	3 600	4 200	4 800	5 400	6 000
14	1 400	2 100	2 800	3 500	4 200	4 900	5 600	6 300	7 000
15	1 500	2 250	3 000	3 750	4 500	5 250	6 000	6 750	7 500
16	1 600	2 400	3 200	4 000	4 800	5 600	6 400	7 200	8 000
18	1 800	2 700	3 600	4 500	5 400	6 300	7 200	8 100	9 000
20	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	10 000
21	2 100	3 150	4 200	5 250	6 300	7 350	8 400	9 450	10 500
24	2 400	3 600	4 800	6 000	7 200	8 400	9 600	10 800	12 000
27	2 700	4 050	5 400	6 750	8 100	9 450	10 800	12 150	13 500
30	3 000	4 500	6 000	7 500	9 000	10 500	12 000	13 500	15 000
33	3 300	4 950	6 600	8 250	9 900	11 450	13 200	14 850	16 500
36	3 600	5 400	7 200	9 000	10 800	12 600	14 400	16 200	18 000
39	3 900	5 850	7 800	9 750	11 700	13 650	15 600	17 550	19 500
42	4 200	6 300	8 400	10 500	12 600	14 700	16 800	18 900	21 000
45	4 500	6 750	9 000	11 250	13 500	15 750	18 000	20 250	22 500
48	4 800	7 200	9 600	12 000	14 400	16 800	19 200	21 600	24 000
54	5 400	8 100	10 800	13 500	16 200	18 900	21 600	24 300	27 000
60	6 000	9 000	12 000	15 000	18 000	21 000	24 000	27 000	30 000
66	6 600	9 900	13 200	16 500	19 800	23 100	26 400	29 700	33 000
72	7 200	10 800	14 400	18 000	21 600	25 200	28 800	32 400	36 000
78	7 800	11 700	15 600	19 500	23 400	27 300	31 200	35 100	39 000
84	8 400	12 600	16 800	21 000	25 200	29 400	33 600	37 800	42 000
90	9 000	13 500	18 000	22 500	27 000	31 500	36 000	40 500	45 000
96	9 600	14 400	19 200	24 000	28 800	33 600	38 400	43 200	48 000
102	10 200	15 300	20 400	25 500	30 600	35 700	40 800	45 900	51 000
108	10 800	16 200	21 600	27 000	32 400	37 800	43 200	48 600	54 000
120	12 000	18 000	24 000	30 000	36 000	42 000	48 000	54 000	60 000
132	13 200	19 800	26 400	33 000	39 600	46 200	52 800	59 400	66 000
144	14 400	21 600	28 800	36 000	43 200	50 400	57 600	64 800	72 000

NOTE—The values in this table are equal to $2PD$, where P is the pressure class in psi and D is the nominal diameter in inches.

joints with laminated overlay, bell-and-spigot joints with laminated overlay, flanged, bell-and-spigot adhesive bonded and threaded.

6.9 *Longitudinal Strength:* :

6.9.1 *Beam Strength*—For pipe sizes up to 27 in. (686 mm), the pipe shall withstand, without failure, the beam loads specified in Table 11, when tested in accordance with 8.7.1. For pipe sizes larger than 27 in., and alternatively for smaller sizes, adequate beam strength is demonstrated by tensile and compression tests conducted in accordance with 8.7.2 and 8.7.3 respectively, for pipe wall specimens oriented in the longitudinal direction, using the minimum tensile and compression strengths specified in Table 11.

6.9.2 *Longitudinal Tensile Strength*—All pipe manufactured under this specification shall have a minimum axial tensile elongation at failure of 0.25% and meet or exceed the longitudinal tensile strength shown for each size and class in Table 12 and Table 13, when tested in accordance with 8.7.2.

NOTE 14—The values listed in Table 12 are the minimum criteria for products made to this standard. The values may not be indicative of the axial strength of some products, or of the axial strength required by some installation conditions and joint configurations.

6.9.3 Conformance to the requirements of 6.9.1 shall satisfy the requirements of 6.9.2 for those pipe sizes and classes where the minimum longitudinal tensile strength values of Table 11 are equal to the values of Table 12. Conformance to the requirements of 6.9.2 shall satisfy the longitudinal tensile strength requirements of 6.9.1.

7. Sampling

7.1 *Lot*—Unless otherwise agreed upon by the purchaser and the supplier, one lot shall consist of 100 lengths of each type, grade, and size of pipe produced.

7.2 *Production Tests*—Select one pipe at random from each lot and take one specimen from the pipe barrel to determine conformance of the material to the workmanship, dimensional, and strength requirements of 6.1, 6.2, 6.6, and 6.7 respectively. Unless otherwise agreed upon between purchaser and supplier, all pipes (up to 54 in. diameter) shall meet the soundness requirements of 6.4.

7.3 *Qualification Tests*—Sampling for qualification tests is not required unless otherwise agreed upon by the purchaser and the supplier. Qualification tests, for which a certification and test report shall be furnished when requested by the purchaser, include the following:

7.3.1 Sanitary sewer service, long-term chemical test.

7.3.2 Industrial service resin component chemical test. A copy of the resin manufacturer's test report may be used as the basis of acceptance for this test as agreed upon by the purchaser and the supplier.

7.3.3 Long-term hydrostatic pressure test.

7.3.4 Joint-tightness test, see 6.8.

7.3.5 Longitudinal strength test, including:

7.3.5.1 Beam strength, and

7.3.5.2 Longitudinal tensile strength.

TABLE 10 Minimum Hoop Tensile Strength of Pipe Wall SI Units

Nominal Diameter in.	Hoop Tensile Strength, kN/m Width								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	140	210	280	350	420	490	560	630	700
10	175	263	350	438	525	613	700	788	875
12	210	315	420	525	630	735	840	945	1 050
14	245	368	490	613	735	858	980	1 103	1 225
15	263	394	525	656	788	919	1 050	1 181	1 313
16	280	420	560	700	840	980	1 120	1 260	1 400
18	315	473	630	788	945	1 103	1 226	1 418	1 575
20	350	525	700	875	1 050	1 225	1 400	1 575	1 750
21	368	552	735	919	1 103	1 287	1 470	1 654	1 838
24	420	630	840	1 050	1 260	1 470	1 680	1 890	2 100
27	473	709	945	1 181	1 418	1 654	1 890	2 126	2 363
30	525	788	1 050	1 313	1 575	1 838	2 100	2 363	2 625
33	578	866	1 155	1 444	1 733	2 004	2 310	2 599	2 888
36	630	945	1 260	1 575	1 890	2 205	2 520	2 835	3 150
39	683	1 024	1 365	1 706	2 048	2 389	2 730	3 071	3 413
42	735	1 103	1 470	1 838	2 205	2 573	2 940	3 308	3 675
45	788	1 181	1 575	1 969	2 363	2 756	3 150	3 544	3 938
48	840	1 260	1 680	2 100	2 520	2 940	3 360	3 780	4 200
54	945	1 418	1 890	2 363	2 835	3 308	3 780	4 253	4 725
60	1 050	1 575	2 100	2 625	3 150	3 675	4 200	4 725	5 250
66	1 155	1 733	2 310	2 888	3 465	4 043	4 620	5 198	5 775
72	1 260	1 890	2 520	3 150	3 780	4 410	5 040	5 670	6 300
78	1 365	2 048	2 730	3 413	4 095	4 778	5 460	6 143	6 825
84	1 470	2 205	2 940	3 675	4 410	5 145	5 880	6 615	7 350
90	1 575	2 363	3 150	3 938	4 725	5 513	6 300	7 088	7 875
96	1 680	2 520	3 360	4 200	5 040	5 880	6 720	7 560	8 400
102	1 785	2 678	3 570	4 463	5 355	6 248	7 140	8 033	8 925
108	1 890	2 835	3 780	4 725	5 670	6 615	7 560	8 505	9 450
120	2 100	3 150	4 200	5 250	6 300	7 350	8 400	9 450	10 500
132	2 310	3 465	4 620	5 775	6 930	8 085	9 240	10 395	11 550
144	2 520	3 780	5 040	6 300	7 560	8 820	10 800	11 340	12 600

7.4 *Control Tests*—The following tests are considered control requirements and shall be performed as agreed upon between the purchaser and the supplier.

7.4.1 *Soundness Test*—60 in. (1524 mm) diameter pipe and larger

7.4.2 Perform sampling and testing for the control requirements for sanitary sewer service at least once annually.

7.4.3 Perform sampling and testing for the control requirements for hydrostatic design basis at least once every two years.

7.5 For individual orders, conduct only those additional tests and number of tests specifically agreed upon between purchaser and supplier.

8. Test Methods

8.1 *Dimensions*:

8.1.1 *Diameters*:

8.1.1.1 *Inside Diameter*—Take inside diameter measurements at a point approximately 6 in. (152 mm) from the end of the pipe section using a steel tape or an inside micrometer with graduations of 1⁄16 in. (1 mm) or less. Take two 90° opposing measurements at each point of measurement and average the readings.

8.1.1.2 *Outside Diameter*—Determine in accordance with Test Method D 3567.

8.1.2 *Length*—Measure with a steel tape or gage having graduations of 1⁄16 in. (1 mm) or less. Lay the tape or gage on or inside the pipe and measure the overall laying length of the pipe.

8.1.3 *Wall Thickness*—Determine in accordance with Test Method D 3567.

8.1.4 *Squareness of Pipe Ends*—Rotate the pipe on a mandrel or trunions and measure the runout of the ends with a dial indicator. The total indicated reading is equal to twice the distance from a plane perpendicular to the longitudinal axis of the pipe. Alternatively, when the squareness of the pipe ends is rigidly fixed by tooling, the tooling may be verified and reinspected at intervals frequent enough to assure that the squareness of the pipe ends is maintained within tolerance.

8.2 *Chemical Tests*:

8.2.1 *Sanitary-Sewer Service*—Test the pipe in accordance with Test Method D 3681.

8.2.1.1 *Long-Term*—To find if the pipe meets the requirements of 6.3.1, determine at least 18 failure points in accordance with Test Method D 3681.

8.2.1.2 *Alternative Qualification Procedure*—Test four specimens each at the 10 and 10 000 h minimum strains given in Table 4 and test five specimens each at the 100 and 1000 h minimum strains given in Table 4. Consider the product qualified if all 18 specimens are tested without failure for at least the prescribed times given in Table 4 (that is, 10, 100, 1000 or 10 000 h respectively).

8.2.1.3 *Control Requirements*—Test at least six specimens in accordance with one of the following procedures and record the results.

8.2.1.4 Test at least 3 specimens at each of the strain levels corresponding to the 100- and 1000-h failure times from the product's regression line established in 8.2.1.

TABLE 11 Beam Strength Test Loads

Nominal Diameter, in.	Beam Load, *P*,		Minimum Longitudinal Tensile Strength, per Unit of Circumference,		Minimum Longitudinal Compressive Strength per Unit of Circumference,	
	lbf	kN	lbf/in.	(kN/m)	lbf/in.	kN/m
8	800	3.6	580	102	580	102
10	1 200	5.3	580	102	580	102
12	1 600	7.1	580	102	580	102
14	2 200	9.8	580	102	580	102
15	2 600	11.6	580	102	580	102
16	3 000	13.3	580	102	580	102
18	4 000	17.8	580	102	580	102
20	4 400	19.6	580	102	580	102
21	5 000	22.2	580	102	580	102
24	6 400	28.5	580	102	580	102
27	8 000	35.6	580	102	580	102
30	. . .	. . .	580	102	580	102
33	. . .	. . .	640	111	640	111
36	. . .	. . .	700	122	700	122
39	. . .	. . .	780	137	780	137
42	. . .	. . .	800	140	800	140
45	. . .	. . .	860	150	860	150
48	. . .	. . .	920	161	920	161
51	. . .	. . .	980	171	980	171
54	. . .	. . .	1 040	182	1 040	182
60	. . .	. . .	1 140	200	1 140	200
66	. . .	. . .	1 260	220	1 260	220
72	. . .	. . .	1 360	238	1 360	238
78	. . .	. . .	1 480	260	1 480	260
84	. . .	. . .	1 600	280	1 600	280
90	. . .	. . .	1 720	301	1 720	301
96	. . .	. . .	1 840	322	1 840	322
102	. . .	. . .	1 940	340	1 940	340
108	. . .	. . .	2 060	360	2 060	360
114	. . .	. . .	2 180	382	2 180	382
120	. . .	. . .	2 280	400	2 280	400
132	. . .	. . .	2 520	440	2 520	440
144	. . .	. . .	2 740	480	2 740	480

8.2.1.5 When the alternative method described in 8.2.1.2 is used to qualify the product, test at least three specimens each at the 100 and 1000 h minimum strains given in Table 4 for at least 100 and 1000 h respectively.

8.2.1.6 The control test procedures of 8.2.1.5 may be used as an alternative procedure to the reconfirmation procedure described in Test Method D 3681 for those products evaluated by the alternative qualification procedure described in 8.2.1.2.

8.2.2 *Industrial Service*—The resin component of the liner or of the surface layer, or both, to be subjected to an aggressive service environment, shall be tested in accordance with Test Method C 581, except that the specimens tested shall be representative of the laminate construction used in the liner or surface layer, or both.

8.3 *Soundness*—Determine soundness by a hydrostatic proof test procedure. Place the pipe in a hydrostatic pressure testing machine that seals the ends and exerts no end loads. Fill the pipe with water, expelling all air, and apply internal water pressure at a uniform rate not to exceed 50 psi (345 kPa)/s until the test pressure shown in Table 5 for the applicable class is reached. Maintain this pressure for a minimum of 30 s. The pipe shall show no visual signs of weeping, leakage, or fracture of the structural wall.

8.4 *Long-Term Hydrostatic Pressure*—Determine the long-term hydrostatic pressure at 50 years in accordance with Procedure B of Practice D 2992, with the following exceptions permitted:

8.4.1 Test at ambient temperatures within the limits of 50°F (10°C) and 110°F (43.5°C) and report the temperature range experienced during the tests.

NOTE 15—Tests indicate no significant effects on long-term hydrostatic pressure within the ambient temperature range specified.

8.4.2 Determine the hydrostatic design basis for the glass-fiber reinforcement in accordance with the method in Annex A1.

8.4.3 Calculate the long-term hydrostatic pressure and categorize by class in accordance with Table 6. Annex A1.6 explains how to calculate the long-term hydrostatic pressure.

8.5 *Stiffness*—Determine the pipe stiffness ($F/\Delta y$) at 5 % deflection for the specimen, using the apparatus and procedure of Test Method D 2412, with the following exceptions permitted:

8.5.1 Measure the wall thickness to the nearest 0.01 in. (0.25 mm).

8.5.2 Load the specimen to 5 % deflection and record the load. Then load the specimen to deflection level A per Table 8 and examine the specimen for visible damage evidenced by surface cracks. Then load the specimen to deflection level B per Table 8 and examine for evidence of structural damage, as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall. Calculate the pipe stiffness at 5 % deflection.

TABLE 12 Longitudinal Tensile Strength of Pipe Wall

Inch-Pound Units									
Nominal Diameter, in.	Longitudinal Tensile Strength, lbf/in. of Circumference								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	580	580	580	580	580	580	580	580	580
10	580	580	580	580	580	580	580	653	726
12	580	580	580	580	644	644	697	784	871
14	580	580	580	626	751	751	813	914	1 016
15	580	580	580	671	805	805	870	980	1 089
16	580	580	580	716	859	859	929	1 045	1 161
18	580	580	608	759	911	911	972	1 094	1 215
20	580	580	675	844	1 013	1 013	1 080	1 215	1 350
21	580	580	709	886	1 063	1 063	1 134	1 276	1 418
24	580	608	810	1 012	1 215	1 215	1 296	1 458	1 620
27	580	683	911	1 139	1 367	1 367	1 458	1 644	1 823
30	580	714	952	1 190	1 428	1 428	1 499	1 686	1 873
33	640	785	1 047	1 309	1 570	1 570	1 648	1 854	2 060
36	700	857	1 142	1 428	1 713	1 713	1 798	2 023	2 248
39	780	928	1 237	1 547	1 856	1 856	1 948	2 192	2 435
42	800	999	1 332	1 666	1 998	1 998	2 098	2 360	2 622
45	860	999	1 332	1 666	1 998	1 998	2 126	2 392	2 658
48	920	1 045	1 393	1 742	2 090	2 090	2 268	2 552	2 835
51	980	1 110	1 480	1 850	2 220	2 220	2 410	2 711	3 012
54	1 040	1 176	1 567	1 959	2 351	2 351	2 552	2 876	3 189
60	1 140	1 306	1 742	2 177	2 612	2 612	2 835	3 189	3 544
66	1 260	1 437	1 916	2 395	2 873	2 873	3 119	3 508	3 898
72	1 360	1 567	2 090	2 612	3 135	3 135	3 402	3 827	4 253
78	1 480	1 580	2 106	2 633	3 159	3 159	3 475	3 909	4 344
84	1 600	1 701	2 268	2 835	3 402	3 402	3 742	4 210	4 678
90	1 720	1 823	2 430	3 038	3 645	3 645	4 010	4 511	5 012
96	1 840	1 944	2 592	3 240	3 888	3 888	4 277	4 811	5 346
102	1 940	2 066	2 754	3 443	4 131	4 131	4 544	5 112	5 680
108	2 060	2 191	2 916	3 645	4 374	4 374	4 811	5 413	6 014
114	2 180	2 309	3 078	3 848	4 617	4 617	5 079	5 714	6 348
120	2 280	2 430	3 240	4 050	4 860	4 860	5 346	6 014	6 683
132	2 520	2 673	3 564	4 455	5 340	5 340	5 881	6 616	7 351
144	2 740	2 918	3 888	4 860	5 832	5 832	6 415	7 217	8 019

8.5.3 For production testing, only one specimen need be tested to determine the pipe stiffness.

8.5.4 The maximum specimen length may be 12 in. (305 mm), or the length necessary to include stiffening ribs if they are used, whichever is greater.

NOTE 16—As an alternative to determining pipe stiffness using the apparatus and procedure of Test Method D 2412, the supplier may submit to the purchaser for approval a test method and test evaluation based on Test Method D 790 accounting for the substitution of curved test specimens and measurement of stiffness at 5 % deflection.

8.6 *Hoop-Tensile Strength*—Determine hoop tensile strength by Test Method D 2290, except that the sections on apparatus and test specimens may be modified to suit the size of the specimens to be tested, and the maximum load rate may not exceed 0.10 in./min (2.54 mm/min). Alternatively, Test Method D 638 may be employed. Specimen width may be increased for pipe wall thickness greater than 0.55 in (13.97 mm). Means may be provided to minimize the bending moment imposed during the test. Three specimens shall be cut from the test sample. Record the load to fail each specimen and determine the specimen width as close to the break as possible. Use the measured width and failure load to calculate the hoop-tensile strength.

8.6.1 *Alternative Minimum Hoop-Tensile Strength Requirement*—As an alternative, the minimum hoop-tensile strength values may be determined through the use of the following formula:

$$F = (S_i/S_r)\,(P_r) \tag{2}$$

where:

F = required minimum hoop-tensile strength, lbf/in.,
S_i = initial design hoop tensile stress, psi,
S_r = hoop tensile stress at rated operating pressure, psi,
P = rated operating pressure class, psi, and
r = inside radius of pipe, in.

The value for S_i should be established by considering the variations in glass reinforcement strength and manufacturing methods, but in any case, should not be less than the 95 % lower confidence value on stress at 0.1 h, as determined by the manufacturer's testing carried out in accordance with 6.5. The value for S_r should be established from the manufacturer's hydrostatic design basis.

NOTE 17—A value of F less than 4 Pr results in a lower factor of safety on short term loading than required by the values in Table 9.

8.7 *Longitudinal Strength* :

8.7.1 *Beam Strength*—Place a 20-ft (6.1-m) nominal length of pipe on saddles at each end. Hold the ends of the pipe round during the test. Apply the beam load for the diameter of pipe shown in Table 11 simultaneously to the pipe through two saddles located at the third points of the pipe (see Fig. 2). Maintain the loads for not less than 10 min with no evidence of failure. The testing apparatus shall be designed to minimize stress concentrations at the loading points.

TABLE 13 Longitudinal Tensile Strength of Pipe Wall

Nominal Diameter, in.	Longitudinal Tensile Strength, kN/m of Circumference (SI Units)								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	102	102	102	102	102	102	102	102	102
10	102	102	102	102	102	102	102	114	127
12	102	102	102	102	113	113	122	137	153
14	102	102	102	110	132	132	142	160	178
15	102	102	102	118	141	141	152	172	191
16	102	102	102	125	150	150	163	183	203
18	102	102	106	133	160	160	170	192	213
20	102	102	118	148	177	177	189	213	236
21	102	102	124	155	186	186	199	223	248
24	102	106	142	177	213	213	227	255	284
27	102	102	156	199	239	239	255	288	319
30	102	125	167	208	250	250	263	295	328
33	111	137	183	229	275	275	289	325	361
36	122	150	200	250	300	300	315	354	394
39	137	163	217	271	325	325	341	384	426
42	140	175	233	292	350	350	367	413	459
45	150	175	233	292	350	350	372	419	465
48	161	183	244	305	366	366	397	447	496
51	171	194	259	324	389	389	422	475	527
54	182	206	274	343	412	412	447	504	558
60	200	229	305	381	457	457	496	558	621
66	220	252	336	419	503	503	546	614	683
72	238	274	366	457	549	549	596	670	745
78	260	277	369	461	553	553	609	685	761
84	280	298	397	496	596	596	655	737	819
90	301	319	426	532	638	638	702	790	878
96	322	340	454	567	681	681	749	843	936
102	340	362	482	603	723	723	796	895	995
108	360	384	511	638	766	766	843	948	1 053
114	382	404	539	674	809	809	889	1 001	1 112
120	400	426	567	709	851	851	936	1 053	1 170
132	440	468	624	780	935	935	1 030	1 159	1 287
144	480	511	681	851	1 021	1 021	1 123	1 264	1 404

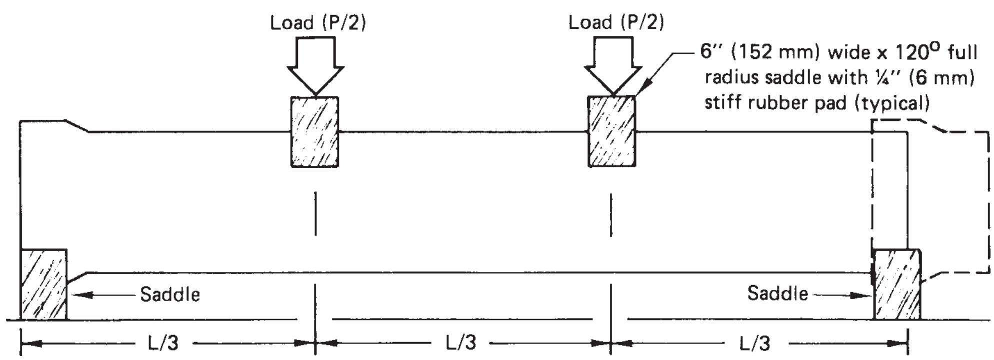

FIG. 2 Beam Strength-Test Setup

8.7.2 *Longitudinal Tensile Strength*—Determine in accordance with Test Method D 638, except the provisions for maximum thickness shall not apply.

8.7.3 *Longitudinal Compressive Strength*—Determine in accordance with Test Method D 695.

9. Packaging, Marking, and Shipping

9.1 Mark each length of pipe that meets or is part of a lot that meets the requirements of this specification at least once, in letters not less than ½ in. (12 mm) in height and of bold-type style in a color and type that remains legible under normal handling and installation procedures. Include in the marking the nominal pipe size, manufacturer's name or trademark, ASTM Specification number D 3754, type, liner, grade, class, and stiffness in accordance with the designation code in 4.2.

9.2 Prepare pipe for commercial shipment in such a way as to ensure acceptance by common or other carriers.

9.3 All packing, packaging, and marking provisions of Practice D 3892 shall apply to this specification.

ANNEXES

(Mandatory Information)

A1. ALTERNATIVE HYDROSTATIC DESIGN METHOD

A1.1 The following symbols are used:

S = tensile stress in the glass-fiber reinforcement in the hoop orientation corrected for the helix angle, psi,
P = internal pressure, psig,
P_l = long-term hydrostatic pressure, psig,
D = nominal inside pipe diameter, in.,
t_h = actual cross-sectional area of glass-fiber reinforcement applied around the circumference of the pipe, in.^{2}/in.,
θ = plane angle between hoop-oriented reinforcement and longitudinal axis of the pipe (helix angle), and
HDB = hydrostatic design basis, psi.

A1.2 The hydrostatic design is based on the estimated tensile stress of reinforcement in the wall of the pipe in the circumferential (hoop) orientation that will cause failure after 50 years of continuously applied pressure, as described in 8.4 and Practice D 2992, Procedure B. Strength requirements are calculated using the strength of hoop-oriented glass reinforcements only, corrected for the helix angle of the fibers.

A1.3 *Hoop-Stress Calculation,* derived from the ISO formula for hoop stress, is as follows:

$$S = PD/2(t_h \sin \theta)$$

This stress is used as the ordinate (long-term strength) in calculating the regression line and lower confidence limit in accordance with Practice D 2992, Annexes A1 and A3.

NOTE A1.1—The calculated result for S may be multiplied by the factor 6.985 to convert from psi to kPa.

A1.4 *Hydrostatic Design Basis*—The value of S is determined by extrapolation of the regression line to 50 years in accordance with Practice D 2992.

A1.5 *Hydrostatic Design Basic Categories*—Convert the value of the HDB to internal hydrostatic pressure in psig as follows:

$$P_1 = 2\,(t_h \sin \theta)\,(\mathrm{HDB})/D$$

The pipe is categorized in accordance with Table A1.1.

NOTE A1.2—The calculated result P_1 may be multiplied by the factor 6.895 to convert from psig to kPa.

A1.6 *Pressure Class Rating*—The classes shown in Table A1.1 are based on the intended working pressure in psig for commonly encountered conditions of water service. The purchaser should determine the class of pipe most suitable to the installation and operating conditions that will exist on the project on which the pipe is to be used by multiplying the values of P_1 from Table A1.1 by a service (design) factor 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 in 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 A1.3—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 evaluating fully 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.

TABLE A1.1 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure, P_1, gage, psi (kPa)
C50	90 (621)
C75	135 (931)
C100	180 (1241)
C125	225 (1551)
C150	270 (1862)
C175	315 (2172)
C200	360 (2482)
C225	405 (2792)
C250	450 (3103)

A2. CALCULATIONS OF LOWER CONFIDENCE (LCL) AND LOWER PREDICTION (LPL) LIMITS

$$h_{LCL} = (a + bf_o) - ts\sqrt{\frac{(f_o - F)^2}{U} + \frac{1}{N}}$$

$$h_{LPL} = (a + bf_o) - ts\sqrt{\frac{(f_o - F)^2}{U} + \frac{1}{N} + 1}$$

where all symbols are as defined in Annexes A1 and A3 of Practice D 2992 except:

f_o = log of stress (strain) level of interest

NOTE A2.1—Of the expected failures at stress (strain) f_o 97.5 % will occur after h_{LPL}. The average failure time at stress (strain) f_o will occur later than h_{LCL} 97.5 % of the time.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN CORROSION PERFORMANCE REQUIREMENTS

X1.1 From Molin and Leonhardt, the expression for bending strain is given as: $\epsilon_b = D_f\,(t/d)\,(\delta v/d)$. With the common acceptance that these pipes must be capable of withstanding 5 % deflection long-term, the maximum installed bending strain may be expressed as:

$$\epsilon_b \max = (0.05)\,(D_f)\,(t/d)$$

Using the AWWA C-950 long-term bending factor of safety of 1.50, the minimum strain corrosion performance extrapolated to 50 years must be:

$$E_{scv} \geq (0.075)\,(D_f)\,(t/d)$$

X1.2 The shape factor, D_f, is dependent on both the pipe stiffness and the installation (for example, backfill material, backfill density, compaction method, haunching, trench configuration, native-soil characteristics and vertical loading). Assuming conservatively, installations achieved by tamped compaction with inconsistent haunching that will limit long-term deflections to 5 %, the following values of D_f *have been selected to be realistic, representative and limiting. Substituting these values in the above equation for* E_{SCV} yields the minimum required strain corrosion performances given below and in Table 4.

Pipe Stiffness (psi)	D_f	Minimum E_{SCV} Performance
9	8.0	0.60 (t/d)
18	6.5	0.49 (t/d)
36	5.5	0.41 (t/d)
72	4.5	0.34 (t/d)

NOTE X1.1—Products may have used limits of other than 5 % long-term deflection. In such cases, the requirements should be proportionally adjusted. For example, a 4 % long-term limiting deflection would result in a 50 year requirement of 80 % of Table 4, while a 6 % limiting deflection would yield a requirement of 120 % of Table 4.

X1.3 *Alternative Strain Corrosion Test Requirements:*

X1.3.1 At 0.1 h (6 min), the required strain corrosion performance is based on the level B deflections from Table 6 as follows:

$$\epsilon \text{ test} \geq Df \left[\frac{t}{Id + \delta V/2}\right]\left[\frac{\delta V}{d + \delta V/2}\right] \quad \text{(X1.1)}$$

or

$$\epsilon \text{ test} \geq Df\,(t/d)\,(\delta V/d)\left(\frac{1}{1 + \delta V/2d}\right)^2 \quad \text{(X1.2)}$$

Df for parallel plate loading is 4.28. Making the other substitutions yield:

Pipe Stiffness (psi)	Level B $\delta v\,/\,d$ (%)	Minimum Test
9	30	0.97 (t/d)
18	25	0.85 (t/d)
36	20	0.71 (t/d)
72	15	0.56 (t/d)

X1.3.2 The minimum strain values at 10, 100, 1000, and 10 000 h given in Table 4 are defined by a straight line connecting the points at 6 min and 50 years on a log-log plot.

X2. INSTALLATION

X2.1 This specification is a material performance and purchase specification only and does not include requirements for engineering design, pressure surges, bedding, backfill, or the relationship between earth cover load, and the strength of the pipe. However, experience has shown that successful performance of this product depends upon the proper type of bedding and backfill, pipe characteristics, and care in the field construction work. The purchaser of the fiberglass pressure pipe specified herein is cautioned that he must properly correlate the field requirements with the pipe requirements and provide adequate inspection at the job site.

X3. RECOMMENDED METHODS OF DETERMINING GLASS CONTENT

X3.1 Determine glass content as follows:

X3.1.1 By ignition loss analysis in accordance with Test Method D 2584 or ISO 1172.

X3.1.2 As a process control, by weight of the glass fiber reinforcement applied by machine into the pipe structure.