Designation: D 3754 – 06

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 156 in. (4000 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 slip-lining and rehabilitation of existing pipelines. Pipe covered by this specification is intended to operate at internal gage pressures of 450 psi (3103 kPa) 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:*

[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), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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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 res (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 surfa layer			
4	Class[C]	C50	C100	C150	C200	C250	C300	C350	C400	C45
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 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).

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

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 (gr operating pressure (class), and pipe stiffness. Table 1 lis types, liners, grades, classes, and stiffnesses that are cove

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

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

NOTE 4—Examples of the designation codes are as follows: (*1*) A D 3754-1-1-3-C50-A for glass-fiber-reinforced aggregate and poly resin mortar pipe with a reinforced thermoset liner and an unrein polyester resin and sand surface layer, for operation at 50 psi (345 and having a minimum pipe stiffness of 9 psi (62 kPa). (*2*) A D 3754-4-2-6-C200-C for glass-fiber-reinforced epoxy resin pipe wi unreinforced thermoset liner, no surface layer, for operation at 20 (1380 kPa) and having a minimum pipe stiffness of 36 psi (248 kP

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

5. Materials and Manufacture

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

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

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

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.

22 *Aggregate*—A siliceous sand conforming to the re-ments of Specification C 33, except that the requirements dation shall not apply.

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

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

Joints—The pipe shall have a joining system that shall de for fluid tightness for the intended service condition. A ular type of joint may be restrained or unrestrained and le or rigid depending on the specific configuration and n conditions.

.1 *Unrestrained*—Pipe joints capable of withstanding al pressure but not longitudinal forces.

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

.1.2 *Mechanical Coupling Joint*, with elsastomeric seals.

.1.3 *Butt Joint*, with laminated overlay

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

.2 *Restrained*—Pipe joints capable of withstanding inter-ressure and longitudinal tensile loads.

.2.1 Joints similar to those in 5.4.1.1 with supplemental ining elements.

.2.2 *Butt Joint*, with laminated overlay.

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

.2.4 *Bell-and-Spigot*, adhesive-bonded-joint: Three types hesive-bonded joints are premitted by this standard as ows:

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

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

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

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

.2.6 *Threaded Joints*.

.2.7 *Mechanical Coupling*, an elastomeric sealed cou-g with supplemental restraining elements.

E 6—Other types of joints may be added as they become commer-y available.

E 7—Restrained joints typically increase service loads on the pipe ater than those experienced with unrestrained joints. The purchaser tioned to take into consideration all conditions that may be ntered in the anticipated service and to consult the manufacturer ding the suitability of a particular type and class of pipe for service restrained joint systems.

5 *Gaskets*—Elastomeric gaskets, when used with this e, 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* 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.

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	...	...	...	...
156	±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.

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 produce an altered neutral axis position, it is necessary to evaluate results and establish requirements substituting $2y$ 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 accep for the service conditions. Where service conditions have been evaluated, a suitable resin may also be selected agreement between the manufacturer and purchaser.

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

6.4 *Soundness*—Unless otherwise agreed upon bet purchaser and supplier, test each length of pipe up to 5 (1370 mm) diameter hydrostatically without leakage or cr ing, at the internal hydrostatic proof pressures specified fo applicable class in Table 5Table 7Table 8 when teste accordance with 8.3. For sizes over 54 in., the frequenc hydrostatic leak tests shall be as agreed upon by purchase supplier.

6.5 *Hydrostatic Design Basis*:

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

TABLE 3 Nominal Outside Diameters (OD) and Tolerances

NOTE—The external diameter of the pipe at the spigots shall be within the tolerances given in the table, and the manufacturer shall declare his allowable maximum and minimum spigot diameters. Some pipes are manufactured such that the entire pipe meets the OD tolerances while other pipes meet the tolerances at the spigots, in which case, if such pipes are cut (shortened) the ends may need to be calibrated to meet the 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 −0.040	9.05	±0.06
10	10.750	+0.108 −0.048	11.10	
12	12.750	+0.128 −0.056	13.20	
14	14.000	+0.140 −0.062	15.30	+0.05 −0.08
16	16.000	+0.160 −0.070	17.40	
18	. . .	. . .	19.50	
20	. . .	. . .	21.60	
24	. . .	. . .	25.80	
30	. . .	. . .	32.00	+0.08 −0.06
36	. . .	. . .	38.30	
42	. . .	. . .	44.50	
48	. . .	. . .	50.80	
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
700				718	+1.0	-2.2
800				820	+1.0	-2.4
900				924	+1.0	-2.6
1000				1026	+2.0	-2.6
1200				1229	+2.0	-2.6
1400				1434	+2.0	-2.8
1600				1638	+2.0	-2.8
1800				1842	+2.0	-3.0
2000				2046	+2.0	-3.0
2200				2250	+2.0	-3.2
2400				2453	+2.0	-3.4
2600				2658	+2.0	-3.6
2800				2861	+2.0	-3.8
3000				3066	+2.0	-4.0
3200				3270	+2.0	-4.2
3400				3474	+2.0	-4.4
3600				3678	+2.0	-4.6
3800				3882	+2.0	-4.8
4000				4086	+2.0	-5.0

TABLE 4 Minimum Sanitary Sewer Pipe Chemical Requirements

Pipe Stiffness, psi (kPa)	ϵ_{scv} 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)
C100	200 (1379)
C150	300 (2068)
C200	400 (2757)
C250	500 (3447)
C300	600 (4136)
C350	700 (4826)
C400	800 (5515)
C450	900 (6205)

TABLE 6 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C100	180 (1241)
C150	270 (1862)
C200	360 (2482)
C250	450 (3103)
C300	540 (3722)
C350	630 (4343)
C400	720 (4963)
C450	810 (5584)

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 %

6.5.2 *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, 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 suffic strength to exhibit the minimum pipe stiffness ($F/\Delta y$) speci in Table 7 when tested in accordance with 8.5. At deflec level A per Table 8, there shall be no visible damage in the specimen evidenced by surface cracks. At deflection lev per Table 8, there shall be no indication of structural damag evidenced by interlaminar separation, separation of the line surface layer (if incorporated) from the structural wall, ten failure of the glass-fiber reinforcement, fracture, or buckling the pipe wall.

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

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

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

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

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

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

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

6.8 *Joint Tightness*—All joints shall meet the labora performance requirements of Specification D 4161. U strained joints shall be tested with a fixed end closure condi and restrained joints shall be tested with a free end clo

NOTE—The values in th

Nominal Diameter (in.)	C50 (psi)
8	800
10	1000
12	1200
14	1400
15	1500
16	1600
18	1800
20	2000
21	2100
24	2400
27	2700
30	3000
33	3300
36	3600
39	3900
42	4200
45	4500
48	4800
51	5100
54	5400
60	6000
66	6600
72	7200
78	7800
84	8400
90	9000
96	9600
102	10 20
108	10 80
114	11 40
120	12 00
132	13 20
144	14 40
156	15 60

condition. Rigid joints requirements of D41 joints with laminated nated overlay, flange threaded.

6.9 *Longitudinal S*

6.9.1 *Beam Strengt* the pipe shall withs specified in Table 11, pipe sizes larger than adequate beam streng pression tests conduc respectively, for pipe dinal direction, using strengths specified in

6.9.2 *Longitudinal* under this specificati elongation at failure tudinal tensile strengt 12 and Table 13, whe

NOTE 14—The values products made to this sta axial strength of some pr

TABLE 9 Minimum Hoop Tensile Strength of Pipe Wall

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

Inch-Pound Units									
Nominal Diameter (in.)	Hoop Tensile Strength, lbf/in. Width								
	Pressure Class								
	C50 (psi)	C100 (psi)	C150 (psi)	C200 (psi)	C250 (psi)	C300 (psi)	C350 (psi)	C400 (psi)	C450 (psi)
8	800	1600	2400	3200	4000	4800	5600	6400	7200
10	1000	2000	3000	4000	5000	6000	7000	8000	9000
12	1200	2400	3600	4800	6000	7200	8400	9600	10 800
14	1400	2800	4200	5600	7000	8400	9800	11 200	12 600
15	1500	3000	4500	6000	7500	9000	10 500	12 000	13 500
16	1600	3200	4800	6400	8000	9600	11 200	12 800	14 400
18	1800	3600	5400	7200	9000	10 800	12 600	14 400	16 200
20	2000	4000	6000	8000	10 000	12 000	14 000	16 000	18 000
21	2100	4200	6300	8400	10 500	12 600	14 700	16 800	18 900
24	2400	4800	7200	9600	12 000	14 400	16 800	19 200	21 600
27	2700	5400	8100	10 800	13 500	16 200	18 900	21 600	24 300
30	3000	6000	9000	12 000	15 000	18 000	21 000	24 000	27 000
33	3300	6600	9900	13 200	16 500	19 800	23 100	26 400	29 700
36	3600	7200	10 800	14 400	18 000	21 600	25 200	28 800	32 400
39	3900	7800	11 700	15 600	19 500	23 400	27 300	31 200	35 100
42	4200	8400	12 600	16 800	21 000	25 200	29 400	33 600	37 800
45	4500	9000	13 500	18 000	22 500	27 000	31 500	36 000	40 500
48	4800	9600	14 400	19 200	24 000	28 800	33 600	38 400	43 200
51	5100	10 200	15 300	20 400	25 500	30 600	35 700	40 800	45 900
54	5400	10 800	16 200	21 600	27 000	32 400	37 800	43 200	48 600
60	6000	12 000	18 000	24 000	30 000	36 000	42 000	48 000	54 000
66	6600	13 200	19 800	26 400	33 000	39 600	46 200	52 800	59 400
72	7200	14 400	21 600	28 800	36 000	43 200	50 400	57 600	64 800
78	7800	15 600	23 400	31 200	39 000	46 800	54 600	62 400	70 200
84	8400	16 800	25 200	33 600	42 000	50 400	58 800	67 200	75 600
90	9000	18 000	27 000	36 000	45 000	54 000	63 000	72 000	81 000
96	9600	19 200	28 800	38 400	48 000	57 600	67 200	76 800	86 400
102	10 200	20 400	30 600	40 800	51 000	61 200	71 400	81 600	91 800
108	10 800	21 600	32 400	43 200	54 000	64 800	75 600	86 400	97 200
114	11 400	22 800	34 200	45 600	57 000	68 400	79 800	91 200	10 2600
120	12 000	24 000	36 000	48 000	60 000	72 000	84 000	96 000	108 000
132	13 200	26 400	39 600	52 800	66 000	79 200	92 400	105 600	118 800
144	14 400	28 800	43 200	57 600	72 000	86 400	100 800	115 200	129 600
156	15 600	31 200	46 800	62 400	78 000	93 600	109 200	124 800	140 400

condition. Rigid joints shall be exempt from angular deflection requirements of D4161. Rigid joints typically include butt 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

TABLE 10 Minimum Hoop Tensile Strength of Pipe Wall

SI Units									
	Hoop Tensile Strength N/mm Width								
Pressure Class	C50	C100	C150	C200	C250	C300	C350	C400	C450
Nominal Diameter (mm)	345 (kPa)	689 (kPa)	1034 (kPa)	1379 (kPa)	1724 (kPa)	2069 (kPa)	2414 (kPa)	2759 (kPa)	3103 (kPa)
200	138	276	414	552	690	828	966	1104	1241
250	173	345	517	690	862	1035	1207	1380	1552
300	207	413	620	827	1034	1241	1448	1655	1862
350	242	482	724	965	1207	1448	1690	1931	2172
375	259	517	776	1034	1293	1552	1811	2069	2327
400	276	551	827	1103	1379	1655	1931	2207	2482
450	311	620	931	1241	1552	1862	2173	2483	2793
500	345	689	1034	1379	1724	2069	2414	2759	3103
550	380	758	1137	1517	1896	2276	2655	3035	3413
600	414	827	1241	1655	2069	2483	2897	3311	3724
700	483	965	1448	1931	2414	2897	3380	3863	4344
750	518	1034	1551	2069	2586	3104	3621	4139	4655
850	587	1171	1758	2344	2931	3517	4104	4690	5275
900	621	1240	1861	2482	3103	3724	4345	4966	5585
1000	690	1378	2068	2758	3448	4138	4828	5518	6206
1100	759	1516	2275	3034	3793	4552	5311	6070	6827
1150	794	1585	2378	3172	3965	4759	5552	6346	7137
1200	828	1654	2482	3310	4138	4966	5794	6622	7447
1300	897	1791	2688	3585	4482	5379	6276	7173	8068
1400	966	1929	2895	3861	4827	5793	6759	7725	8688
1500	1035	2067	3102	4137	5172	6207	7242	8277	9309
1700	1173	2343	3516	4689	5862	7035	8208	9381	10 550
1800	1242	2480	3722	4964	6206	7448	8690	9932	11 171
2000	1380	2756	4136	5516	6896	8276	9656	11 036	12 412
2200	1518	3032	4550	6068	7586	9104	10 622	12 140	13 653
2300	1587	3169	4756	6343	7930	9517	11 104	12 691	14 274
2400	1656	3307	4963	6619	8275	9931	11 587	13 243	14 894
2600	1794	3583	5377	7171	8965	10 759	12 553	14 347	16 136
2800	1932	3858	5790	7722	9654	11 586	13 518	15 450	17 377
2900	2001	3996	5997	7998	9999	12 000	14 001	16 002	17 997
3000	2070	4134	6204	8274	10 344	12 414	14 484	16 554	18 618
3400	2346	4685	7031	9377	11 723	14 069	16 415	18 761	21 100
3600	2484	4961	7445	9929	12 413	14 897	17 381	19 865	22 342
4000	2760	5512	8272	11 032	13 792	16 552	19 312	22 072	24 824

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.

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° opposite 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.

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	1200	(5.3)	580	(102)	580	(102)
12	1600	(7.1)	580	(102)	580	(102)
14	2200	(9.8)	580	(102)	580	(102)
15	2600	(11.6)	580	(102)	580	(102)
16	3000	(13.3)	580	(102)	580	(102)
18	4000	(17.8)	580	(102)	580	(102)
20	4400	(19.6)	580	(102)	580	(102)
21	5000	(22.2)	580	(102)	580	(102)
24	6400	(28.5)	580	(102)	580	(102)
27	8000	(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	...	...	1040	(182)	1040	(182)
60	...	...	1140	(200)	1140	(200)
66	...	...	1260	(220)	1260	(220)
72	...	...	1360	(238)	1360	(238)
78	...	...	1480	(260)	1480	(260)
84	...	...	1600	(280)	1600	(280)
90	...	...	1720	(301)	1720	(301)
96	...	...	1840	(322)	1840	(322)
102	...	...	1940	(340)	1940	(340)
108	...	...	2060	(360)	2060	(360)
114	...	...	2180	(382)	2180	(382)
120	...	...	2280	(400)	2280	(400)
132	...	...	2520	(440)	2520	(440)
144	...	...	2740	(480)	2740	(480)
156	...	...	2964	(519)	2964	(519)

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 inspected 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.

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:

TABLE 12 Longitudinal Tensile Strength of Pipe Wall

Inch-Pound Units

Nominal Diameter (in.)	Longitudinal Tensile Strength lbf/in. of Circumference — Pressure Class C50 (psi)	C100 (psi)	C150 (psi)	C200 (psi)	C250 (psi)	C300 (psi)	C350 (psi)	C400 (psi)	C450 (psi)
8	580	580	580	580	580	624	700	800	900
10	580	580	580	580	650	780	875	1000	1125
12	580	580	580	624	780	936	1050	1200	1350
14	580	580	609	728	910	1092	1225	1400	1575
15	580	580	653	780	975	1170	1313	1500	1688
16	580	580	696	832	1040	1248	1400	1600	1800
18	580	580	783	936	1170	1404	1575	1800	2025
20	580	580	870	1040	1300	1560	1750	2000	2250
21	580	609	914	1092	1365	1638	1838	2100	2363
24	580	696	1044	1248	1560	1800	2100	2400	2700
27	580	783	1175	1404	1688	2025	2363	2700	3038
30	580	870	1305	1560	1875	2250	2625	3000	3375
33	627	957	1436	1716	2063	2475	2888	3300	3713
36	684	1044	1566	1800	2250	2700	3150	3600	4050
39	741	1131	1697	1872	2340	2808	3276	3744	4212
42	798	1218	1827	2016	2520	3024	3528	4032	4536
45	855	1305	1958	2160	2700	3240	3780	4320	4860
48	912	1392	2088	2304	2880	3456	4032	4608	5184
51	969	1479	2219	2448	3060	3672	4284	4896	5508
54	1026	1566	2349	2592	3240	3726	4347	4968	5589
60	1140	1740	2520	2880	3600	4140	4830	5520	6210
66	1254	1914	2673	3036	3795	4554	5313	5808	6534
72	1368	2088	2916	3312	4140	4968	5796	6336	7128
78	1482	2106	3159	3432	4290	5148	6006	6864	7722
84	1596	2268	3402	3696	4620	5292	6174	7056	7938
90	1710	2430	3645	3960	4950	5670	6615	7380	8303
96	1824	2592	3888	4224	5280	6048	7056	7680	8640
102	1938	2754	4131	4488	5610	6426	7497	8160	9180
108	2052	2916	4374	4752	5940	6804	7938	8640	9720
114	2166	3078	4617	5016	6270	7182	8379	9120	10 260
120	2280	3240	4860	5280	6600	7560	8820	9600	10 800
132	2508	3564	5346	5808	7260	8316	9702	10 560	11 880
144	2736	3888	5832	6336	7920	9072	10 584	11 520	12 960
156	2964	4212	6318	6864	8580	9828	11 466	12 480	14 040

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, tens failure of the glass-fiber reinforcement, fracture, or buckli the pipe wall. Calculate the pipe stiffness at 5 % deflectio

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

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

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

8.6 *Hoop-Tensile Strength*—Determine hoop ten strength by Test Method D 2290, except that the sections apparatus and test specimens may be modified to suit the s of the specimens to be tested, and the maximum load rate m not exceed 0.10 in./min (2.54 mm/min). Alternatively, Method D 638 may be employed. Specimen width may increased for pipe wall thickness greater than 0.55 in (1 mm). Means may be provided to minimize the bend moment imposed during the test. Three specimens shall be from the test sample. Record the load to fail each specimen.

TABLE 13 Longitudinal Tensile Strength of Pipe Wall

SI Units									
Longitudinal Tensile Strength N/mm of Circumference									
Pressure Class	C50	C100	C150	C200	C250	C300	C350	C400	C450
Nominal Diameter (mm)	345 (kPa)	689 (kPa)	1034 (kPa)	1379 (kPa)	1724 (kPa)	2069 (kPa)	2414 (kPa)	2759 (kPa)	3103 (kPa)
200	102	102	102	102	102	109	123	140	158
250	102	102	102	102	114	137	153	175	197
300	102	102	102	109	137	164	184	210	236
350	102	102	107	127	159	191	215	245	276
375	102	102	114	137	171	205	230	263	296
400	102	102	122	146	182	219	245	280	315
450	102	102	137	164	205	246	276	315	355
500	102	102	152	182	228	273	306	350	394
550	102	107	160	191	239	287	322	368	414
600	102	122	183	219	273	315	368	420	473
700	102	137	206	246	296	355	414	473	532
750	102	152	229	273	328	394	460	525	591
850	110	168	251	301	361	433	506	578	650
900	120	183	274	315	394	473	552	630	709
1000	130	198	297	328	410	492	574	656	738
1100	140	213	320	353	441	530	618	706	794
1150	150	229	343	378	473	567	662	757	851
1200	160	244	366	403	504	605	706	807	908
1300	170	259	388	429	536	643	750	857	965
1400	180	274	411	454	567	652	761	870	979
1500	200	305	441	504	630	725	846	967	1087
1700	220	335	468	532	665	797	930	1017	1144
1800	240	366	511	580	725	870	1015	1110	1248
2000	260	369	553	601	751	902	1052	1202	1352
2200	279	397	596	647	809	927	1081	1236	1390
2300	299	426	638	693	867	993	1158	1292	1454
2400	319	454	681	740	925	1059	1236	1345	1513
2600	339	482	723	786	982	1125	1313	1429	1608
2800	359	511	766	832	1040	1192	1390	1513	1702
2900	379	539	809	878	1098	1258	1467	1597	1797
3000	399	567	851	925	1156	1324	1545	1681	1891
3400	439	624	936	1017	1271	1456	1699	1849	2080
3600	479	681	1021	1110	1387	1589	1853	2017	2270
4000	519	738	1106	1202	1503	1721	2008	2185	2459

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:

$$F = (S_i/S_r)(P_r) \quad (2)$$

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.

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,

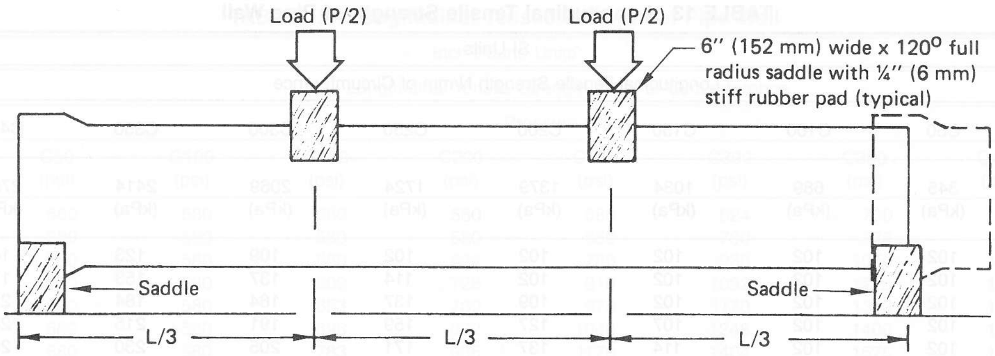

FIG. 2 Beam Strength-Test Setup

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.

10. Keywords

10.1 fiberglass pipe; sewer pipe; industrial pipe; pressure pipe; strain corrosion; hydrostatic design basis

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.

TABLE A1.1 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C100	180 (1241)
C150	270 (1862)
C200	360 (2482)
C250	450 (3103)
C300	540 (3722)
C350	630 (4343)
C400	720 (4963)
C450	810 (5584)

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:

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

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 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.

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 fie construction work. The purchaser of the fiberglass press pipe specified herein is cautioned that he must prope correlate the field requirements with the pipe requirements a 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 fi reinforcement applied by machine into the pipe structure.

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