



# Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe<sup>1</sup>

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 ( $\epsilon$ ) 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:

- C 33 Specification for Concrete Aggregates<sup>2</sup>
- C 581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced

- Structures Intended for Liquid Service<sup>3</sup>
  - D 638 Test Method for Tensile Properties of Plastics<sup>4</sup>
  - D 695 Test Method for Compressive Properties of Rigid Plastics<sup>4</sup>
  - D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials<sup>4</sup>
  - D 883 Terminology Relating to Plastics<sup>4</sup>
  - D 1600 Terminology for Abbreviated Terms Relating to Plastics<sup>4</sup>
  - D 2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method<sup>5</sup>
  - D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading<sup>3</sup>
  - D 2584 Test Method for Ignition Loss of Cured Reinforced Resins<sup>6</sup>
  - D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings<sup>3</sup>
  - D 3567 Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings<sup>3</sup>
  - D 3681 Test Method for Chemical Resistance of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition<sup>3</sup>
  - D 3892 Practice for Packaging/Packing of Plastics<sup>7</sup>
  - D 4161 Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals<sup>3</sup>
  - F 412 Terminology Relating to Plastic Piping Systems<sup>3</sup>
  - F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe<sup>3</sup>
- ### 2.2 ISO Standard:
- ISO 1172 Textile Glass Reinforced Plastics—Determination of Loss on Ignition<sup>8</sup>
- ### 2.3 AWWA Standard:

<sup>1</sup> 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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<sup>2</sup> Annual Book of ASTM Standards, Vol 04.02.

<sup>3</sup> Annual Book of ASTM Standards, Vol 08.04.

<sup>4</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 15.03.

<sup>6</sup> Annual Book of ASTM Standards, Vol 08.02.

<sup>7</sup> Annual Book of ASTM Standards, Vol 08.03.

<sup>8</sup> Available from American National Standards Institute (ANSI), 11 West 42nd Street, 13th Floor, New York, NY 10036.

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

AWWA C-950 Glass-Fiber Reinforced Thermosetting Resin Pressure Pipe<sup>9</sup>

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.

<sup>9</sup> Available from the American Water Works Association, 6666 West Quincey Ave., Denver, CO 80235.

TABLE 1 General Designation Requirements for Fiberglass Pressure Pipe

Designation	Property	Cell Limits <sup>A</sup>											
		1		2		3		4					
1	Type	glass-fiber-reinforced thermosetting polyester <sup>B</sup> resin mortar (RPMP polyester) <sup>B</sup>		glass-fiber-reinforced thermosetting polyester <sup>B</sup> resin (RTRP polyester) <sup>B</sup>		glass-fiber-reinforced thermosetting epoxy resin mortar (RPMP epoxy)		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 <sup>B</sup>		2 polyester <sup>B</sup> resin surface layer—nonreinforced <sup>B</sup>		3 polyester <sup>B</sup> resin and sand surface layer nonreinforced		4 epoxy resin surface layer—reinforced		5 epoxy resin surface layer—nonreinforced		6 No surface layer	
4	Class <sup>C</sup>	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) <sup>ABC</sup>					

<sup>A</sup>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.

<sup>B</sup>For the purposes of this standard, polyester includes vinyl ester resin.

<sup>C</sup>Based on operating pressure in psig (numerals).

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.

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 elastomeric 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 permitted 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 1/8 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 ±1/4 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.



FIG. 1 Typical Joints

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

Nominal Diameter, <sup>A</sup> in.	Tolerances, in.	Nominal Metric Diameter, <sup>B</sup> mm	ID Range, <sup>B</sup> mm		Tolerance <sup>B</sup> on Declared ID, mm
			Minimum	Maximum	
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	...	...	...	...

<sup>A</sup>Inside diameters other than those shown shall be permitted by agreement between purchaser and supplier.

<sup>B</sup>Values are taken from International Standards Organization documents. Parentheses indicate non-preferred diameters.

### 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 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



**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	
10	10.750	-0.040	11.10	±0.06
12	12.750	+0.108	13.20	
14	14.000	-0.048	15.30	
16	16.000	+0.128	17.40	
18	...	-0.056	19.50	+0.05
20	...	+0.160	21.60	
24	...	-0.070	25.80	
30	...	...	32.00	-0.08
36	...	...	38.30	
42	...	...	44.50	
48	...	...	50.80	
54	...	...	57.56	+0.08
60	...	...	61.61	

  

Metric Pipe Size, mm	Ductile Iron Pipe Equivalent, mm	Tolerance, mm	International OD, mm	Tolerance, mm
200	222	-3.0	...	...
250	274	-3.1	...	...
300	326	-3.3	310	-1.0
350	378	-3.4	361	-1.2
400	429	-3.5	412	-1.4
450	...	...	463	-1.6
500	532	-3.8	514	-1.8
600	635	-4.0	616	-2.0
700	738	-4.3	718	-2.2
800	842	-4.5	820	-2.4
900	945	-4.8	924	-2.6
1000	1048	-5.0	1026	-2.6
1100	1152	-5.3	...	...
1200	1255	-5.5	1229	-2.6
1400	1462	-6.0	1434	-2.8
1600	1668	-7.4	1638	-2.8
1800	1875	-8.2	1842	-3.0
2000	2082	-9.0	2046	-3.0
2200	...	...	2250	-3.2
2400	...	...	2453	-3.4
2600	...	...	2658	-3.6
2800	...	...	2861	-3.8
3000	...	...	3066	-4.0

**TABLE 4 Minimum Sanitary Sewer Pipe Chemical Requirements**

Pipe Stiffness, psi (kPa)	$\epsilon_{scv}$					
	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.

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 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.

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

**TABLE 7 Minimum Stiffness at 5 % Deflection**

Nominal Diameter, in.	Pipe Stiffness, psi (kPa)			
	A	Designation		
		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 %

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 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.