American Water Works Association

ANSI/AWWA C950-01

(Revision of ANSI/AWWA C950-95)

AWWA STANDARD

FOR

FIBERGLASS PRESSURE PIPE

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AMERICAN WATER WORKS ASSOCIATION

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AWWA Standard

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

Foreword

This foreword is for information only and is not part of ANSI/AWWA C950.

I. Introduction.

I.A. *Background.* This standard provides direction and guidance in selecting and purchasing fiberglass pipe for use as pressure pipe in water distribution (including services) and transmission systems for both aboveground and belowground installations.

This standard describes 1-in. through 144-in. (25-mm through 3,600-mm) diameter pressure pipes. The primary materials used are thermosetting polyester or epoxy resins, glass-fiber reinforcement, and, if used, aggregate. There are five pressure classes, which range from 50 psi through 250 psi (345 kPa through 1,724 kPa), in 50-psi (345-kPa) increments. Stiffness classes described are 9, 18, 36, and 72 psi (62, 124, 248, and 496 kPa). This standard may be used to the extent applicable for other sizes, pressure classes, and stiffness classes.

I.B. *History.* In June 1971, the AWWA Engineering and Construction Technical and Professional Committee organized the Reinforced Plastics Committee to evaluate both the use of reinforced plastics in the water-supply industry and the need for appropriate AWWA standards. The Reinforced Plastics Committee found sufficient use and interest to support a recommendation that a standard be developed for fiberglass pipe. The Standards Council authorized the formation of the Standards Committee on Thermosetting Fiberglass Reinforced Plastic Pipe in October 1972, and committee organization was completed in December 1974. The first edition of the standard was approved by the AWWA Board of Directors on Jan. 25, 1981. The second edition was approved on June 23, 1988. The third edition was approved on Jan. 22, 1995. This edition was approved on June 17, 2001.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.

2. Specific policies of the state or local agency.

3. Two standards developed under the direction of NSF, ANSI†/NSF‡ 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.

4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex,*§ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C950-01 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.

2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

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*Persons in Canada, Mexico, and non-North American countries should contact the appropriate authority having jurisdiction.

†American National Standards Institute, 25 W. 43rd St., New York, NY 10036.

‡NSF International, 789 N. Dixboro Rd., Ann Arbor, MI 48105.

§Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

II. Special Issues.

II.A. *Nominal Metric Pipe Sizes, Dimensions, and Tolerances.* Nominal metric pipe sizes, dimensions, and tolerances were obtained from International Organization for Standardization (ISO) specification 7370, Glass Fibre Reinforced Thermosetting Plastics (GRP) Pipes and Fittings—Nominal Diameters, Specified Diameters, and Standard Lengths, and proposed addenda to that document.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* The following items should be covered in the purchaser's specifications:

1. Standard used—that is, ANSI/AWWA C950, Standard for Fiberglass Pressure Pipe, of latest revision.
2. Pipe diameter size and series (Sec. 4.5.1).
3. Pressure classes (Sec. 4.6).
4. Stiffness classes (Sec. 4.7).
5. Specific service and installation considerations.
6. Lineal feet of each pressure and stiffness class and size.
7. Whether plant inspection is required (Sec. 5.1.1).

The purchaser may also specify the following:

1. Cell classification (Sec. 4.3).
2. Standard laying lengths (Sec. 4.5.2).
3. Joint configuration (Sec. 4.9).
4. Line layout showing pressure zones, including applicable design and transient pressures within zones and points of change between zones.

III.B. *Manufacturer Options and Alternatives.* The following items should be provided in the manufacturer's specifications:

1. Cell classification (Sec. 4.3).
2. Stiffness class (Sec. 4.7).
3. Joint details (Sec. 4.9).
4. Nominal wall thickness.
5. Weight.
6. Total quantity of jointing materials and field allowances.

When requested by the purchaser, it is understood that the manufacturer also will supply the following:

1. Special design calculations.
2. Special lengths (Sec. 4.5.2).
3. Special preparations needed for shipment (Sec. 6.2).
4. Affidavit of compliance (Sec. 6.3).

III.C. *Modification to Standard.* Any modifications to the provisions, definitions, or terminology in this standard must be provided in the purchaser's or manufacturer's specifications.

IV. Major Revisions. Major revisions made to the standard in this edition include the following:

1. Flexible joint has been included in the definitions (Sec. 3).

2. A statement on materials has been included which references the Safe Drinking Water Act (Sec. 4.4.1).

3. External pipe dimensions for metric outside diameter (OD) series pipe have been updated (Table 5 and Table 6).

4. Joint descriptions and performance requirements have been clarified (Sec. 4.9).

5. Deflection levels for stiffness tests have been clarified (Sec. 5.1.2.2.2).

6. Methods of computing appropriate deflection values for other pipe stiffness levels have been added (Sec. 5.1.2.2.2.1).

7. Information on proportionally adjusting deflections to maintain equivalent in-use safety margins have been added (5.1.2.2.2.2).

8. Modifications to the axial tensile strength tests have been made to exclude the provisions for maximum thickness in ASTM D638, the minimum axial elongation to failure has been set at 0.25 percent, and a note added requiring higher axial strength for pipes subject to beam bending, longitudinal thrust loads, or any unusual axial tensile forces (Sec. 5.1.2.4 and Sec. 5.1.2.4.1).

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer & Technical Support Group, (303) 794-7711 ext. 6283, FAX (303) 794-6303, or write to the group at 6666 W. Quincy Ave., Denver, CO 80235.

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AWWA STANDARD FOR

FIBERGLASS PRESSURE PIPE

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes the fabrication and the testing of nominal 1-in. through 144-in. (25-mm through 3,600-mm) fiberglass pipe and joining systems for use in both aboveground and belowground water systems. Service and distribution piping systems and transmission piping systems are included.

Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes. Epoxy-resin and polyester-resin systems are described, and commercial-grade E-type glass is specified as the glass-fiber reinforcement material in the pipe wall. Liner materials incorporated include thermosetting or thermoplastic resin, reinforced or unreinforced, with or without fillers. Pressure classes described are 50, 100, 150, 200, and 250 psig (345, 689, 1,034, 1,379, and 1,724 kPa). Stiffness classes described are 9, 18, 36, and 72 psi (62, 124, 248, and 496 kPa). This standard may be used to the extent applicable for other diameters, pressure classes, and stiffness classes. For information on design, hydraulics, and installation, refer to AWWA Manual M45, *Fiberglass Pipe Design*.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for fiberglass pressure pipe, including design, fabrication, and testing requirements.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving fiberglass pressure pipe. This standard can be used as a guide for manufacturing this type of fiberglass pressure pipe. The stipulations of this standard apply when this document has been referenced and then only to fiberglass pressure pipe.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, these documents form a part of this standard to the extent specified within the standard. In case of conflict, the requirements of this standard shall prevail.

ASTM* C33—Standard Specification for Concrete Aggregates.

ASTM D638—Standard Test Method for Tensile Properties of Plastics.

ASTM D695—Standard Test Method for Compressive Properties of Rigid Plastics.

ASTM D1599—Standard Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.

ASTM D2105—Standard Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.

ASTM D2290—Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method.

ASTM D2412—Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

ASTM D2992—Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.

ASTM D3517—Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe.

ASTM D3567—Standard Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.

ASTM D3681—Standard Test Method for Chemical Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition.

*American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

ASTM D4161—Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

ASTM D5365—Standard Test Method for Long-Term Ring-Bending Strain of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.

ASTM F477—Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Aggregate:* Siliceous sand conforming to ASTM C33, except that the requirements for gradation need not apply.

2. *Centrifugal casting:* A process used to manufacture tubular goods by applying resin and reinforcement to the inside of a mold that is rotated and heated, subsequently polymerizing the resin system. The outside diameter (OD) of the finished pipe is determined by the inside diameter (ID) of the mold tube. The ID of the finished pipe is determined by the amount of material introduced into the mold. Other materials that will not adversely affect the laminate performance may be introduced in the process during manufacture of the pipe.

3. *Constructor:* The party that provides the work and materials for placement or installation.

4. *Epoxy resin (thermosetting):* A polymer containing two or more three-membered rings, each consisting of one oxygen and two carbon atoms. The polymer is cured by cross-linking with an amine or anhydride hardener, with or without heat, catalyst, or both.

5. *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, and pigments or dyes. Thermoplastic or thermosetting liners or coatings may be included.

6. *Filament winding:* A process used to manufacture tubular goods by winding continuous glass-fiber roving or roving tape onto the outside of a mandrel or core pipe liner in a predetermined pattern under controlled tension. The roving may be saturated with liquid resin or preimpregnated with partially cured resin. Subsequent polymerization of the resin system may require application of heat. The ID of the finished pipe is fixed by the mandrel diameter or the inner diameter of the

core pipe liner. The OD of the finished pipe is determined by the amount of material that is wound on the mandrel or core pipe liner. Other materials may be introduced in the process during the manufacture of the pipe, which will not adversely affect the laminate performance.

7. *Fixed end*: The end of a pipe test specimen with an end closure configuration such that internal pressure produces only hoop and radial stresses in a straight pipe test specimen. Longitudinal thrust is absorbed by separate means, such as tie-rods, etc.

8. *Flexible joint:* A joint that is capable of axial displacement or angular rotation.

9. *Free end*: The end of a pipe test specimen with an end closure configuration such that internal pressure produces longitudinal stresses in addition to hoop and radial stresses in the pipe test specimen.

10. *Glass fabric:* A bidirectional fabric reinforcing material made by the weaving of glass-fiber yarn.

11. *Glass fibers:* A commercial grade of glass E-type filaments with binder and sizing that are compatible with the impregnating resin.

12. *Joint restraint*: A separate external device or structure that is assembled or constructed around a joint to provide restraint to longitudinal tensile forces.

13. *Liner:* A filled or unfilled thermoplastic or thermosetting resin layer, nonreinforced or reinforced, that forms the interior surface of the pipe.

14. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

15. *Mat:* A fibrous material consisting of random-oriented, chopped, or swirled filaments loosely held together with a binder.

16. *Polyester resin (thermosetting):* An ethylenic unsaturated polymer with two or more ester groups, dissolved in a reactive diluent with vinyl unsaturation. The polymer is cured by cross-linking using a free-radical-initiated curing mechanism, such as peroxide catalyst and heat.

17. *Purchaser:* The person, company, or organization that purchases materials or work to be performed.

18. *Purchaser's agent:* The authorized representative of the purchaser who is entrusted with the inspection of materials and production records and the observance of production operations and quality-control tests to ensure that the products comply with the requirements of this standard and of the purchaser.

19. *Reinforced polymer–mortar pipe (RPMP):* A fiberglass pipe with aggregate.

20. *Reinforced thermosetting-resin pipe (RTRP):* A fiberglass pipe without aggregate.

21. *Resin:* Any of a class of solid or pseudosolid organic materials, often of high molecular weight, with no definite melting point. In the broad sense, the term is used to designate any polymer that is a basic material for plastics.

22. *Restrained joint*: Pipe joint capable of withstanding internal pressure and longitudinal tensile loads.

23. *Rigid joint*: A joint that is not capable of axial displacement or angular rotation.

24. *Roving:* A collection of parallel glass strands or filaments, coated with a finish or coupling agent to improve compatibility with resins, gathered without mechanical twist. Roving may be processed in a continuous or chopped form.

25. *Supplier:* The party that supplies materials or services. A supplier may or may not be the manufacturer.

26. *Stiffness class:* The nominal stiffness of a specified pipe. (The stiffness class is determined as specified in Sec. 4.7)

27. *Surface layer:* A filled or unfilled resin layer, nonreinforced or reinforced, that is applied to the exterior surface of the pipe structural wall.

28. *Surfacing mat:* A thin mat of fine fibers used primarily to produce a smooth surface on a reinforced plastic.

29. *Tape:* A unidirectional glass-fiber reinforcement consisting of rovings knitted or woven into ribbon form.

30. *Thermoplastic resin:* A plastic that can be repeatedly softened by heating and hardened by cooling and that in the softened state can be fused or shaped by flow.

31. *Thermosetting resin:* A plastic that, after having been cured by heat or other means, is substantially infusible and insoluble.

32. *Unrestrained joint*: Pipe joint capable of withstanding internal pressure but not longitudinal tensile loads.

33. *Woven roving:* A glass-fiber fabric reinforcing material made by the weaving of glass-fiber roving.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants comprised of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials, such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement, and elastomers, such as used in jointing gaskets and packing glands, may be subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, and so forth, **before** selecting materials for use in that area.

Sec. 4.2 Workmanship

The pipe shall be free from defects, including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that, because of 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.

Sec. 4.3 Cell Classification System

This standard describes products defined by a cell classification system and identifies the method of manufacture (type), construction and materials (grade), and liner construction (liner). The types, grades, and liners are identified in the following paragraphs. It should be noted that all possible combinations of types, grades, and liners may not be commercially available.

4.3.1 *Types.* The product type is determined by the method of manufacture, as follows:

Type I: Filament wound.

Type II: Centrifugally cast.

4.3.2 *Grades.* The product grade is determined by construction (glass-fiber-reinforced or glass-fiber-reinforced mortar) and materials (epoxy or polyester), as follows:

Grade 1: Glass-fiber-reinforced epoxy (RTRP epoxy).

Grade 2: Glass-fiber-reinforced polyester (RTRP polyester).

Grade 3: Glass-fiber-reinforced epoxy mortar (RPMP epoxy).

Grade 4: Glass-fiber-reinforced polyester mortar (RPMP polyester).

4.3.3 *Liners.* The product-liner classification is determined by whether or not a liner is used and, if used, whether it is a thermoplastic, reinforced, or nonreinforced thermoset. Classification of liners is as follows:

Liner A: No liner.

Liner B: Thermoplastic liner.

Liner C: Reinforced thermoset liner.

Liner D: Nonreinforced thermoset liner.

Sec. 4.4 Materials

The resins, reinforcement, colorants, fillers, and other materials, when combined as a composite structure, shall produce pipe products that meet the performance requirements of this standard as specified in Sec. 5.1.2.

4.4.1 *Qualification for potable water service.* Materials shall comply with the requirements of the Safe Drinking Water Act and other federal, state, and local requirements. Legislation is subject to change. Therefore, it is the manufacturer's and purchaser's responsibility to verify the current requirements of federal, state, and local regulations.

4.4.2 *Certification.* Fiberglass pipe intended for use in the transport of potable water shall be evaluated and certified for this use as required by the local authority.* The seal or mark of the laboratory that evaluates the pipe should be included on the fiberglass pipe.

4.4.3 *Gaskets and lubricants.* Gaskets and lubricants shall be made from materials that (1) are compatible with the plastic materials and with each other when used together; (2) will not support the growth of bacteria; and (3) will not adversely affect the potable qualities of water.

Sec. 4.5 Pipe Dimensions

4.5.1 *Diameters.* Pipe diameters and tolerances shall be as shown in Tables 1, 2, 3, 4, 5, and 6 when measured in accordance with ASTM D3567. These tables include dimensions for pipe based on both inside and outside diameters. In the latter case, tables are provided for steel-pipe-equivalent ODs, cast-iron (ductile-iron)-pipe-equivalent ODs, and metric ODs commonly used in international practice.

*See Sec. I.C. Acceptance in the foreword for additional guidance.

As a group, the tables cover nominal pipe sizes 1 in. through 144 in. (25 mm through 3,600 mm); individual tables cover only a portion of the total range.

4.5.2 *Length*. Pipe shall be provided in standard laying lengths as agreed on by the purchaser and manufacturer. A maximum of 15 percent of the footage of each pipe size may be provided in random lengths. Each random length provided shall not vary by more than 25 percent from the standard laying length specified, except for special orders.

NOTE: Common practice in the industry provides for laying lengths of 10, 20, 30, 40, or 60 ft (3, 6, 9, 12, and 18 m).

4.5.3 *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 percent of that nominal wall thickness when measured in accordance with ASTM D3567.

Sec. 4.6 Pressure Classes

The standard pressure classes for pipe shall be 50, 100, 150, 200, and 250 psig (345, 689, 1,034, 1,379, and 1,724 kPa). The pressure classes refer to the maximum sustained working pressure. They are determined in accordance with Sec. 4.6.2 using a design factor of 1.8. The pressure classes may have to be changed for pipes conveying water at elevated temperatures (in accordance with the manufacturer's recommendations) and whenever there is a need to provide more allowance for surge pressure.

For pipe subjected to circumferential bending, the effect of this bending on the hydrostatic design pressure class of the pipe must be considered.

4.6.1 *Thermoplastic lined pipe*. The pressure classes for thermoplastic lined pipe are based on a water temperature of 73.4°F (23°C). The classes may need to be reduced for use at temperatures greater than 73.4°F (23°C). The temperature-derating service factors shall be supplied by the pipe manufacturer.

Table 1 Dimensions for inside diameter series pipe

Nominal Pipe Size		Inside Diameter		Tolerance	
in.	*(mm)*[*]	*in.*	*(mm)*	*in.*	*(mm)*
1	(25)	1.00	(25.4)	±0.06	(±1.5)
1½	(40)	1.50	(38.1)	±0.06	(±1.5)
2	(50)	2.00	(50.8)	±0.06	(±1.5)
2½	(65)	2.50	(63.5)	±0.06	(±1.5)
3	(80)	3.00	(76.2)	±0.12	(±3.0)
4	(100)	4.00	(101.6)	±0.12	(±3.0)
6	(150)	6.00	(152.4)	±0.25	(±6.3)
8	(200)	8.00	(203.2)	±0.25	(±6.3)
10	(250)	10.00	(254.0)	±0.25	(±6.3)
12	(300)	12.00	(304.8)	±0.25	(±6.3)
14	(350)	14.00	(355.6)	±0.25	(±6.3)
15	(375)	15.00	(381.0)	±0.25	(±6.3)
16	(400)	16.00	(406.4)	±0.25	(±6.3)
18	(450)	18.00	(457.2)	±0.25	(±6.3)
20	(500)	20.00	(508.0)	±0.25	(±6.3)
21	(550)	21.00	(533.4)	±0.25	(±6.3)
24	(600)	24.00	(609.6)	±0.25	(±6.3)
27	(700)	27.00	(685.8)	±0.27	(±6.9)
30	(800)	30.00	(762.0)	±0.30	(±7.6)
33	(850)	33.00	(838.2)	±0.33	(±8.4)
36	(900)	36.00	(914.4)	±0.36	(±9.1)
39	(1,000)	39.00	(990.6)	±0.39	(±9.9)
42	(1,100)	42.00	(1,066.8)	±0.42	(±10.7)
45	(1,150)	45.00	(1,143.0)	±0.45	(±11.4)
48	(1,200)	48.00	(1,219.2)	±0.48	(±12.2)
51	(1,300)	51.00	(1,295.4)	±0.51	(±13.0)
54	(1,400)	54.00	(1,371.6)	±0.54	(±13.7)
60	(1,500)	60.00	(1,524.0)	±0.60	(±15.2)
66	(1,700)	66.00	(1,676.4)	±0.66	(±16.8)
72	(1,800)	72.00	(1,828.8)	±0.72	(±18.3)
78	(2,000)	78.00	(1,981.2)	±0.78	(±19.8)
84	(2,200)	84.00	(2,133.6)	±0.84	(±21.3)
90	(2,300)	90.00	(2,286.0)	±0.90	(±22.9)
96	(2,400)	96.00	(2,438.4)	±0.96	(±24.4)
102	(2,600)	102.00	(2,590.8)	±1.00	(±25.4)
108	(2,800)	108.00	(2,743.2)	±1.00	(±25.4)
114	(2,900)	114.00	(2,895.6)	±1.00	(±25.4)
120	(3,000)	120.00	(3,048.0)	±1.00	(±25.4)
132	(3,400)	132.00	(3,352.8)	±1.00	(±25.4)
144	(3,600)	144.00	(3,657.6)	±1.00	(±25.4)

*Closest customary metric equivalent.

Table 2 Metric dimensions for inside diameter (ID) series pipe

Nominal Pipe Size		Inside Diameter					
Metric Dimension*	Closest US Customary Unit Equivalent	Range *mm*		US Customary Unit Equivalent† *in.*		Tolerance	
mm	*in.*	*Minimum*	*Maximum*	*Minimum*	*Maximum*	*mm*	*(in.)*
25	1	23.5	26.5	0.93	1.04	±1.5	(±0.06)
40	1½	38	42	1.50	1.65	±1.5	(±0.06)
50	2	48	52	1.89	2.05	±1.5	(±0.06)
80	3	78	82	3.07	3.23	±1.5	(±0.06)
100	4	97	103	3.82	4.06	±1.5	(±0.06)
150	6	147	153	5.79	6.02	±1.5	(±0.06)
200	8	196	204	7.72	8.03	±1.5	(±0.06)
250	10	246	255	9.69	10.04	±1.5	(±0.06)
300	12	296	306	11.65	12.05	±1.8	(±0.07)
350	14	346	357	13.62	14.06	±2.1	(±0.08)
400	16	396	408	15.59	16.06	±2.4	(±0.09)
450	18	446	459	17.56	18.07	±2.7	(±0.11)
500	20	496	510	19.53	20.08	±3.0	(±0.12)
600	24	595	612	23.43	24.09	±3.6	(±0.14)
700	27	695	714	27.36	28.11	±4.2	(±0.17)
800	30	795	816	31.30	32.13	±4.2	(±0.17)
900	36	895	918	35.24	36.14	±4.2	(±0.17)
1,000	39	995	1,020	39.17	40.16	±4.2	(±0.17)
1,200	48	1,195	1,220	47.05	48.03	±5.0	(±0.20)
1,400	54	1,395	1,420	54.92	55.91	±5.0	(±0.20)
1,600	63	1,595	1,620	62.80	63.78	±5.0	(±0.20)
1,800	72	1,795	1,820	70.67	71.65	±5.0	(±0.20)
2,000	78	1,995	2,020	78.54	79.53	±5.0	(±0.20)
(2,200)	84	2,195	2,220	86.42	87.40	±5.0	(±0.20)
2,400	96	2,395	2,420	94.29	95.28	±6.0	(±0.24)
(2,600)	102	2,595	2,620	102.17	103.15	±6.0	(±0.24)
2,800	108	2,795	2,820	110.04	111.02	±6.0	(±0.24)
(3,000)	120	2,995	3,020	117.91	118.90	±6.0	(±0.24)
3,200	126	3,195	3,220	125.79	126.77	±6.0	(±0.24)
(3,400)	132	3,395	3,420	133.66	134.65	±7.0	(±0.28)
3,600	144	3,595	3,620	141.54	142.52	±7.0	(±0.28)

*Values taken from international practice; values in parentheses indicate nonpreferred diameters.

†US customary unit equivalent ID obtained by dividing millimetres by 25.4.

Table 3 Dimensions for outside diameter (OD) series pipe with steel-pipe-equivalent (IPS) ODs

Nominal Pipe Size		Outside Diameter		Tolerance	
in.	*(mm)**	*in.*	*(mm)*	*in.*	*(mm)*
1	(25)	1.315	(33.40)	+0.060	(+1.52)
				–0.016	(–0.41)
1½	(40)	1.900	(48.26)	+0.060	(+1.52)
				–0.018	(–0.46)
2	(50)	2.375	(60.33)	+0.060	(+1.52)
				–0.018	(–0.46)
2½	(65)	2.875	(73.03)	+0.060	(+1.52)
				–0.018	(–0.46)
3	(80)	3.500	(88.90)	+0.060	(+1.52)
				–0.018	(–0.46)
4	(100)	4.500	(144.30)	+0.060	(+1.52)
				–0.018	(–0.46)
6	(150)	6.625	(168.28)	+0.066	(+1.68)
				–0.028	(–0.71)
8	(200)	8.625	(219.08)	+0.086	(+2.18)
				–0.040	(–1.02)
10	(250)	10.750	(273.05)	+0.108	(+2.74)
				–0.048	(–1.22)
12	(300)	12.750	(323.85)	+0.128	(+3.25)
				–0.056	(–1.42)
14	(350)	14.000	(355.60)	+0.140	(+3.56)
				–0.062	(–1.57)
16	(400)	16.000	(406.40)	+0.160	(+4.06)
				–0.070	(–1.78)

*Closest customary metric equivalent.

Table 4 Dimensions for outside diameter (OD) series pipe with cast-iron (ductile-iron)-pipe-equivalent ODs

Nominal Pipe Size		Outside Diameter		Tolerance	
in.	*(mm)*[*]	*in.*	*(mm)*	*in.*	*(mm)*
2	(50)	2.50	(63.5)	+0.05	(+1.3)
				–0.05	(–1.3)
3	(80)	3.96	(100.6)	+0.06	(+1.5)
				–0.06	(–1.5)
4	(100)	4.80	(121.9)	+0.06	(+1.5)
				–0.06	(–1.5)
6	(150)	6.90	(175.3)	+0.06	(+1.5)
				–0.06	(–1.5)
8	(200)	9.05	(229.9)	+0.06	(+1.5)
				–0.06	(–1.5)
10	(250)	11.10	(281.9)	+0.06	(+1.5)
				–0.06	(–1.5)
12	(300)	13.20	(335.3)	+0.06	(+1.5)
				–0.06	(–1.5)
14	(350)	15.30	(388.6)	+0.05	(+1.3)
				–0.08	(–2.0)
16	(400)	17.40	(442.0)	+0.05	(+1.3)
				–0.08	(–2.0)
18	(450)	19.50	(495.3)	+0.05	(+1.3)
				–0.08	(–2.0)
20	(500)	21.60	(548.6)	+0.05	(+1.3)
				–0.08	(–2.0)
24	(600)	25.80	(655.3)	+0.05	(+1.3)
				–0.08	(–2.0)
30	(800)	32.00	(812.8)	+0.08	(+2.0)
				–0.06	(–1.5)
36	(900)	38.30	(972.8)	+0.08	(+2.0)
				–0.06	(–1.5)
42	(1,100)	44.50	(1,130.3)	+0.08	(+2.0)
				–0.06	(–1.5)
48	(1,200)	50.80	(1,290.3)	+0.08	(+2.0)
				–0.06	(–1.5)
54	(1,800)	57.56	(1,462.0)	+0.08	(+2.0)
				–0.06	(–1.5)
60	(1,500)	61.61	(1,564.9)	+0.08	(+2.0)
				–0.06	(–1.5)

*Closest customary metric equivalent.

Table 5 Metric dimensions for outside diameter (OD) series pipe*

Nominal Size	Closest US Customary Size	External Pipe Diameter	US Equivalent†	Tolerance (mm)	
DN *mm*	*in.*	*mm*	OD *in.*	Upper Limit	Lower Limit
300	12	310	12.20	+1.0	–1.0
350	14	361	14.21	+1.0	–1.2
400	16	412	16.22	+1.0	–1.4
450	18	463	18.23	+1.0	–1.6
500	20	514	20.24	+1.0	–1.8
				+1.0	
600	24	616	24.25	+1.0	–2.0
				+1.0	
700	27	718	28.27	+1.0	–2.2
				+1.0	
800	30	820	32.28	+1.0	–2.4
				+1.0	
900	36	924	36.38	+1.0	–2.6
				+1.0	
1,000	39	1,026	40.39	+1.0	–2.6
				+1.0	
1,200	48	1,229	48.39	+1.0	–2.6
				+1.0	
1,400	54	1,434	56.46	+1.0	–2.8
				+1.0	
1,600	63	1,638	64.49	+1.0	–2.8
				+1.0	
1,800	72	1,842	72.52	+1.0	–3.0
				+1.0	
2,000	78	2,046	80.55	+1.0	–3.0
				+1.0	
2,200	84	2,250	88.58	+1.0	–3.2
				+1.0	
2,400	96	2,453	96.57	+1.0	–3.4
				+1.0	
2,600	102	2,658	104.65	+1.0	–3.6
				+1.0	
2,800	108	2,861	112.64	+1.0	–3.8
				+1.0	
3,000	120	3,066	120.71	+1.0	–4.0
				+1.0	
3,200	126	3,270	128.74	+1.0	–4.2
				+1.0	
3,400	132	3,474	136.77	+1.0	–4.4
3,600	144	3,678	144.80	+1.0	–4.6

*Values taken from international practice.

†US customary unit equivalent OD obtained by dividing millimetres by 25.4.

Table 6 Metric dimensions for outside diameter (OD) series pipe with ductile-iron-pipe-equivalent ODs*

Nominal Size	Closest US Customary Size	External Diameter	US Equivalent†	Tolerance (mm)	
DN *mm*	*in.*	*mm*	OD *in.*	Upper Limit	Lower Limit
100	4	115.0	4.53	+1.0	+0.3
125	5	141.0	5.55	+1.0	+0.2
150	6	167.0	6.57	+1.0	+0.1
200	8	220.0	8.66	+1.0	0.0
250	10	271.8	10.70	+1.0	–0.2
300	12	323.8	12.75	+1.0	–0.3
350	14	375.7	14.79	+1.0	–0.3
400	16	426.6	16.80	+1.0	–0.3
450	18	477.6	18.80	+1.0	–0.4
500	20	529.5	20.85	+1.0	–0.4
600	24	632.5	24.90	+1.0	–0.5

*Values taken from international practice.

†US customary unit equivalent OD obtained by dividing millimetres by 25.4.

4.6.2 *Long-term hydrostatic design pressure.* The pressure classes shall be based on long-term hydrostatic-design-pressure data extrapolated to 50 years, using procedure B of ASTM D2992 or, alternately, with the procedure specified in Annex A.1 of ASTM D3517. Procedure A data from ASTM D2992 may be used in place of procedure B data. End fixtures used during testing shall be representative of the product use as follows:

Service	Test End Fixture
Restrained joints	Free ends
Unrestrained joints	Fixed ends

Sec. 4.7 Stiffness Classes

The standard stiffness classes shall be 9, 18, 36, and 72 psi (62, 124, 248, and 496 kPa) and shall be determined in accordance with Sec. 5.1.2.2.

Sec. 4.8 Long-Term Ring-Bending Strain

4.8.1 *Long-term ring-bending strain, S_b.* Long-term ring-bending strain can be determined with creep-failure tests instrumented to detect an abrupt, significant reduction in mechanical properties. The test data should be statistically extrapolated to establish strength at 50 years. The value for S_b may be determined by testing per

ASTM D5365, using a water test solution with any pH between 5 and 9. If these test results are not available, the value for S_b may be taken as the results of either of the following testing methods:

1. In accordance with ASTM D3681, using 1*N* H_2SO_4.
2. Using results of ASTM D2992, method B, extrapolated to 50 years.

Sec. 4.9 Joint Types and Requirements

The pipe shall have a joining system that shall not leak for the intended service condition. A particular type of joint may be restrained or unrestrained and flexible or rigid depending on the specific joint configuration and design conditions.

4.9.1 *Unrestrained.* Pipe joints capable of withstanding internal pressure but *not* longitudinal tensile loads.

4.9.1.1 Coupling or bell-and-spigot joints. 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.

4.9.1.2 Mechanical couplings joint with elastomeric seals.

4.9.1.3 Butt joint with laminated overlay.

4.9.1.4 Flanged joint. Both integral and loose ring.

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

4.9.2.1 Joints similar to the joints in Sec. 4.9.1.1 but with supplemental restraining elements.

4.9.2.2 Butt joint with laminated overlay.

4.9.2.3 Bell-and-spigot joint with laminated overlay.

4.9.2.4 Bell-and-spigot adhesive bonded joint: Three types of adhesive-bonded joints are permitted by this standard. The permissible adhesive-bonded joints are as follows:

1. Tapered bell and spigot: An adhesive joint that is manufactured with a tapered socket for use in conjunction with a tapered spigot section and a suitable adhesive.
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.
3. Tapered bell and straight spigot: An adhesive joint that is manufactured with a tapered socket for use in conjunction with an untapered spigot and a suitable adhesive.

4.9.2.5 Flanged. Both integral and loose ring.

4.9.2.6 Mechanical. An elastomeric sealed coupling with supplemental restraining elements.

4.9.2.7 Threaded joints.

4.9.3 *Performance requirements*.

4.9.3.1 Joint tightness. All joints shall meet the Laboratory Performance Requirements of Sec. 7 of ASTM D4161. 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, flanged, bell and spigot adhesive bonded and threaded.

4.9.3.2 Gaskets. Elastomeric gaskets shall conform to the requirements of ASTM F477.

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

SECTION 5: VERIFICATION

Sec. 5.1 Inspection and Testing

5.1.1 *Plant inspection by purchaser.* Plant inspection by the purchaser or the omission of this inspection shall not relieve the manufacturer of the responsibility to provide products that comply with the applicable requirements of this standard and of the purchaser.

5.1.1.1 Production notice. When plant inspection is specified by the purchaser, the manufacturer shall provide the purchaser with adequate advance notice of when and where the production of ordered products will commence.

5.1.1.2 Inspection limitations. If a manufacturer desires to exclude inspection of proprietary manufacturing processes, the manufacturer shall so advise the purchaser.

5.1.1.3 Plant access. The purchaser's agent shall have free access to those parts of a manufacturer's plant that are necessary to assure that products comply with all requirements of this standard and of the purchaser. Access may be limited to

areas of the manufacturer's plant not specifically excluded by the terms of Sec. 5.1.1.2.

5.1.1.4 Inspection aids. The manufacturer shall make available to the purchaser's agent, without charge, the tools and assistance necessary for inspection and handling of materials.

5.1.2 *Quality control tests and records.* The manufacturer shall take adequate measures in the production of products to assure compliance with the requirements of this standard. To ensure compliance, the following tests shall be performed at the indicated intervals, unless otherwise specified by the purchaser. The manufacturer shall maintain a record of all quality control tests for a period of not less than two years and, if requested, shall submit the data to the purchaser.

5.1.2.1 Hydrostatic leak tests. Unless otherwise agreed on by the purchaser and supplier, the manufacturer shall perform hydrostatic leak tests to all pipe sizes 1 in. through 54 in. (25 mm through 1,400 mm). For sizes greater than 54 in. (1,400 mm), the frequency of hydrostatic leak tests shall be as agreed on by the manufacturer and purchaser. The pipe shall not fail, leak, or weep when tested at ambient temperatures according to Sec. 5.1.2.1.1.

5.1.2.1.1 A length of pipe, when tested, shall be placed in a hydrostatic-pressure test machine that seals the ends of the pipe. The pipe shall be filled with water, expelling all air, and an internal water pressure shall be applied at a uniform rate until a pressure of two times the pressure class is reached (see Table 7). This test pressure shall be maintained for at least 30 sec. The pipe shall show no visual signs of weeping or leakage. Integral bells, including reinforcement sleeves, if any, or affixed couplings, shall be tested with the pipe.

5.1.2.2 Stiffness tests. The manufacturer shall perform stiffness tests at a frequency of one test for each 100 lengths of pipe produced or from each manufacturing

Table 7 Hydrostatic leak test pressure requirements

Pressure Class		Hydrostatic Test Pressure	
psi	*kPa*	*psi*	*kPa*
50	345	100	689
100	689	200	1,379
150	1,034	300	2,068
200	1,379	400	2,758
250	1,724	500	3,447

run, whichever provides the most frequent sampling of each class and size. The minimum pipe stiffness (F/ΔY) shall be determined at 5 percent deflection using the apparatus and procedure of ASTM D2412, with three exceptions. The exceptions are (1) the wall thickness shall be measured to the nearest 0.01 in. (0.25 mm); (2) the specimen taken from the pipe barrel shall be loaded to 5 percent deflection, the load shall be recorded, and the loading continued to level A deflection (Table 9) and then to level B deflection; and (3) test frequency shall be as specified in this paragraph.

5.1.2.2.1 The pipe shall exhibit, without structural damage, the minimum stiffness specified in Table 8 when tested in accordance with Sec. 5.1.2.2.

5.1.2.2.2 At deflection level A (Table 9), there shall be no interior surface cracks or crazes. At deflection level B (Table 9), there shall be no 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, and fracture or buckling of the pipe wall. Both level A and level B criteria must be met. The pipe stiffness test specimen may be used for these tests.

NOTE: This is a visual observation for quality control purposes only and should not be considered a simulated service test. Table 9 values are based on an in-use long-term deflection limit of 5 percent and provide an appropriate uniform safety margin for all pipe stiffnesses.

5.1.2.2.2.1 For other pipe stiffness levels, appropriate values for level A and level B deflections (Table 9) may be computed as follows:

Level A @ new pipe stiffness (PS) = $9 \times (72/\text{new PS})^{0.33}$

Level B @ new pipe stiffness (PS) = new Level A / 0.6

5.1.2.2.2.2 Because products may have limits of other than 5 percent long-term deflection, level A and level B deflections (Table 9) may be proportionally adjusted to maintain equivalent in-use safety margins. For example, a 4 percent long-term

Table 8 Minimum pipe stiffness requirements for 5 percent deflection

Nominal Pipe Size		Stiffness Class—*psi (kPa)*			
		9 (62)	18 (124)	36 (248)	72 (496)
in.	*(mm)*	Minimum Pipe Stiffness Required—*psi (kPa)*			
1–8	(25–200)	NR*	NR	36.0 (248)	72.0 (496)
10	(250)	NR	18.0 (124)	36.0 (248)	72.0 (496)
12–144	(300–3,600)	9.0 (62)	18.0 (124)	36.0 (248)	72.0 (496)

*Not recommended.

Table 9 Ring deflection without damage or structural failure

	Stiffness Class—*psi (kPa)*			
	9 (62)	18 (124)	36 (248)	72 (496)
Deflection Level	Ring Deflection—% of diameter			
A	18	15	12	9
B	30	25	20	15

NOTE: For other stiffness classes, ring deflection, expressed as a percentage of pipe diameter, is calculated as follows:

Level B = $30(9/\text{pipe stiffness})^{0.33}$

Level A = 0.6 (Level B)

limiting deflection would result in a 20 percent reduction of level A and level B deflections, while a 6 percent limiting deflection would result in a 20 percent increase in level A and level B deflection values.

5.1.2.3 Hoop tensile strength tests. The manufacturer shall perform hoop tensile strength tests at a frequency of one test for each 100 lengths of pipe produced or from each manufacturing run, whichever provides the most frequent sampling of each class and size. The minimum hoop tensile strength properties shall be determined from the average of the test results of three specimens cut from the sample when using the apparatus and procedure of one of the following test methods:

1. ASTM D2290, procedure A. Specimen width shall be appropriate to the diameter and wall thickness of the pipe. Reduced-section specimens are acceptable. A test apparatus with a varying rate of motion may be used, provided the speed of testing does not exceed 0.10 in./min (2.5 mm/min) in accordance with procedure A. Except in cases of disagreement, routine quality control tests may be performed at ambient conditions of temperature and humidity, and calculations need not include the standard deviation.

2. ASTM D638. The widths of specimens may be increased for pipe wall thicknesses greater than 0.55 in. (14 mm). Means may be provided to minimize the bending moment imposed during the test. Except in cases of disagreement, calculations from routine quality control test results need not include the standard deviation.

3. ASTM D1599.

5.1.2.3.1 The pipe shall meet or exceed the minimum short-term hoop tensile strength calculated by Eq 1 or Eq 2, whichever is greater. The minimum short-term hoop tensile strengths calculated per Eq 2 are stated in Table 10.

Table 10 Minimum hoop tensile strength requirements (from Eq 2)

		Pressure Class—*psi* (*kPa*)									
Nominal Pipe Size		50	(345)	100	(689)	150	(1,034)	200	(1,379)	250	(1,724)
in.	*(mm)**	Minimum Hoop Tensile Strength *lbf/in. of width (kN/m of width)*									
1	(25)	100	(18)	200	(35)	300	(53)	400	(70)	500	(88)
1½	(40)	150	(26)	300	(53)	450	(79)	600	(105)	750	(131)
2	(50)	200	(35)	400	(70)	600	(105)	800	(140)	1,000	(175)
2½	(65)	250	(44)	500	(88)	750	(131)	1,000	(175)	1,250	(219)
3	(80)	300	(53)	600	(105)	900	(158)	1,200	(210)	1,500	(263)
4	(100)	400	(70)	800	(140)	1,200	(210)	1,600	(280)	2,000	(350)
6	(150)	600	(105)	1,200	(210)	1,800	(315)	2,400	(420)	3,000	(525)
8	(200)	800	(140)	1,600	(280)	2,400	(420)	3,200	(560)	4,000	(700)
10	(250)	1,000	(175)	2,000	(350)	3,000	(525)	4,000	(700)	5,000	(875)
12	(300)	1,200	(210)	2,400	(420)	3,600	(630)	4,800	(840)	6,000	(1,050)
14	(350)	1,400	(245)	2,800	(490)	4,200	(735)	5,600	(980)	7,000	(1,225)
15	(375)	1,500	(263)	3,000	(525)	4,500	(788)	6,000	(1,050)	7,500	(1,313)
16	(400)	1,600	(280)	3,200	(560)	4,800	(840)	6,400	(1,120)	8,000	(1,400)
18	(450)	1,800	(315)	3,600	(630)	5,400	(945)	7,200	(1,260)	9,000	(1,575)
20	(500)	2,000	(350)	4,000	(700)	6,000	(1,050)	8,000	(1,400)	10,000	(1,750)
21	(550)	2,100	(368)	4,200	(735)	6,300	(1,103)	8,400	(1,470)	10,500	(1,838)
24	(600)	2,400	(420)	4,800	(840)	7,200	(1,260)	9,600	(1,680)	12,000	(2,100)
27	(700)	2,700	(473)	5,400	(945)	8,100	(1,418)	10,800	(1,890)	13,500	(2,363)
30	(800)	3,000	(525)	6,000	(1,050)	9,000	(1,575)	12,000	(2,100)	15,000	(2,625)
33	(850)	3,300	(578)	6,600	(1,155)	9,900	(1,733)	13,200	(2,310)	16,500	(2,888)
36	(900)	3,600	(630)	7,200	(1,260)	10,800	(1,890)	14,400	(2,520)	18,000	(3,150)
39	(1,000)	3,900	(683)	7,800	(1,365)	11,700	(2,048)	15,600	(2,730)	19,500	(3,413)
42	(1,100)	4,200	(735)	8,400	(1,470)	12,600	(2,205)	16,800	(2,940)	21,000	(3,675)
45	(1,150)	4,500	(788)	9,000	(1,575)	13,500	(2,363)	18,000	(3,150)	22,500	(3,938)
48	(1,200)	4,800	(840)	9,600	(1,680)	14,400	(2,520)	19,200	(3,360)	24,000	(4,200)
51	(1,300)	5,100	(893)	10,200	(1,785)	15,300	(2,678)	20,400	(3,570)	25,500	(4,463)
54	(1,400)	5,400	(945)	10,800	(1,890)	16,200	(2,835)	21,600	(3,780)	27,000	(4,725)
60	(1,500)	6,000	(1,050)	12,000	(2,100)	18,000	(3,150)	24,000	(4,200)	30,000	(5,250)
66	(1,700)	6,600	(1,155)	13,200	(2,310)	19,800	(3,465)	26,400	(4,620)	33,000	(5,775)
72	(1,800)	7,200	(1,260)	14,400	(2,520)	21,600	(3,780)	28,800	(5,040)	36,000	(6,300)
78	(2,000)	7,800	(1,365)	15,600	(2,730)	23,400	(4,095)	31,200	(5,460)	39,000	(6,825)
84	(2,200)	8,400	(1,470)	16,800	(2,940)	25,200	(4,410)	33,600	(5,880)	42,000	(7,350)
90	(2,300)	9,000	(1,575)	18,000	(3,150)	27,000	(4,725)	36,000	(6,300)	45,000	(7,875)
96	(2,400)	9,600	(1,680)	19,200	(3,360)	28,800	(5,040)	38,400	(6,720)	48,000	(8,400)
102	(2,600)	10,200	(1,785)	20,400	(3,570)	30,600	(5,355)	40,800	(7,140)	51,000	(8,925)
108	(2,800)	10,800	(1,890)	21,600	(3,780)	32,400	(5,670)	43,200	(7,560)	54,000	(9,450)
114	(2,900)	11,400	(1,995)	22,800	(3,990)	34,200	(5,985)	45,600	(7,980)	57,000	(9,975)
120	(3,000)	12,000	(2,100)	24,000	(4,200)	36,000	(6,300)	48,000	(8,400)	60,000	(10,500)
132	(3,400)	13,200	(2,310)	26,400	(4,620)	39,600	(6,930)	52,800	(9,240)	66,000	(11,550)
144	(3,600)	14,400	(2,520)	28,800	(5,040)	43,200	(7,560)	57,600	(10,080)	72,000	(12,600)

*Closest customary metric equivalent.

$$F = \frac{Si}{Sr}(Pr) \qquad \text{(Eq 1)}$$

$$F = 4.0(Pr) \qquad \text{(Eq 2)}$$

Where:

F = required minimum hoop tensile strength, lbf per inch of width (kN/m)
S_i = initial design hoop tensile strength, psi (kPa)
S_r = hoop tensile stress at pressure class, psi (kPa)
P = specified pressure class from Table 7, psi (kPa)
r = nominal pipe radius, in. [(OD—single wall thickness)/2] (m)

5.1.2.3.2 The values of S_i and S_r should be established from the manufacturer's long-term hydrostatic tests performed in accordance with Sec. 4.6.2. S_i shall be taken as the 95 percent lower-confidence level, back extrapolated to 0.1 hr. This takes into consideration variations in glass-fiber strength and manufacturing methods. S_r is the calculated hoop tensile stress at the pressure class.

5.1.2.4 Axial tensile strength tests. The manufacturer shall perform axial tensile strength tests at a frequency of one test for each 100 lengths of pipe produced or from each manufacturing run, whichever provides the most frequent sampling of each class and size. The minimum axial tensile strength shall be determined from the average of the test results of three specimens cut from the sample when using the apparatus and procedure of ASTM D638, except the provisions for maximum thickness shall not apply, or ASTM D2105, depending on the size of the pipe specimens to be tested.

5.1.2.4.1 The pipe shall have a minimum axial tensile elongation to failure of 0.25 percent and meet or exceed the minimum axial tensile strength requirements listed in Table 11 when tested in accordance with ASTM D638 or ASTM D2105.

NOTE: The values in Table 11 are the minimum criteria and are based on buried pipe without axial thrust loads. Required axial strength for aboveground pipes subject to beam bending, or any pipes that must withstand longitudinal thrust loads or any unusual axial tensile forces, may exceed the values in Table 11.

5.1.2.5 Beam-strength tests. The beam-strength test is a design-qualification test required only when there is a significant change in the design or construction of the pipe. A significant change is considered to occur when the average axial tensile strength as determined in Sec. 5.1.2.4 decreases more than 15 percent. Two methods can be used.

Table 11 Minimum axial tensile strength requirements

Nominal Pipe Size		Pressure Class—*psi (kPa)*									
		50	(345)	100	(689)	150	(1,034)	200	(1,379)	250	(1,724)
in.	*(mm)*[*]	Minimum Axial Tensile Strength *lbf/in. of circumference (kN/m of circumference)*									
1	(25)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
1½	(40)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
2	(50)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
2½	(65)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
3	(80)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
4	(100)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
6	(150)	360	(63)	360	(63)	360	(63)	360	(63)	387	(68)
8	(200)	580	(102)	580	(102)	580	(102)	580	(102)	580	(102)
10	(250)	580	(102)	580	(102)	580	(102)	580	(102)	726	(127)
12	(300)	580	(102)	580	(102)	644	(113)	697	(122)	871	(153)
14	(350)	580	(102)	580	(102)	751	(132)	813	(142)	1,016	(178)
15	(375)	580	(102)	580	(102)	805	(141)	870	(152)	1,089	(191)
16	(400)	580	(102)	580	(102)	859	(150)	929	(163)	1,161	(203)
18	(450)	580	(102)	608	(108)	911	(160)	972	(170)	1,215	(213)
20	(500)	580	(102)	675	(118)	1,013	(177)	1,080	(189)	1,350	(236)
21	(550)	580	(102)	709	(124)	1,063	(186)	1,134	(199)	1,418	(248)
24	(600)	580	(102)	810	(142)	1,215	(213)	1,296	(227)	1,620	(284)
27	(700)	580	(102)	911	(156)	1,367	(239)	1,458	(255)	1,823	(319)
30	(800)	580	(102)	952	(167)	1,428	(250)	1,499	(263)	1,873	(328)
33	(850)	640	(111)	1,047	(183)	1,570	(275)	1,648	(289)	2,060	(361)
36	(900)	700	(122)	1,142	(200)	1,713	(300)	1,798	(315)	2,248	(394)
39	(1,000)	780	(137)	1,237	(217)	1,856	(325)	1,948	(341)	2,435	(426)
42	(1,100)	800	(140)	1,332	(233)	1,998	(350)	2,098	(367)	2,622	(459)
45	(1,150)	860	(150)	1,332	(233)	1,998	(350)	2,126	(372)	2,658	(465)
48	(1,200)	920	(161)	1,393	(244)	2,090	(366)	2,268	(397)	2,835	(496)
51	(1,300)	980	(171)	1,480	(259)	2,200	(389)	2,410	(422)	3,012	(527)
54	(1,400)	1,040	(182)	1,567	(274)	2,351	(412)	2,552	(447)	3,189	(558)
60	(1,500)	1,140	(200)	1,742	(305)	2,612	(457)	2,835	(496)	3,544	(621)
66	(1,700)	1,260	(220)	1,916	(336)	2,873	(503)	3,119	(546)	3,898	(683)
72	(1,800)	1,360	(238)	2,090	(366)	3,135	(549)	3,402	(596)	4,253	(745)
78	(2,000)	1,480	(260)	2,106	(369)	3,159	(553)	3,475	(609)	4,344	(761)
84	(2,200)	1,600	(280)	2,268	(397)	3,402	(596)	3,742	(655)	4,678	(819)
90	(2,300)	1,720	(301)	2,430	(426)	3,645	(638)	4,010	(702)	5,012	(878)
96	(2,400)	1,840	(322)	2,592	(454)	3,888	(681)	4,277	(749)	5,346	(936)
102	(2,600)	1,940	(340)	2,754	(482)	4,131	(723)	4,544	(796)	5,680	(995)
108	(2,800)	2,060	(360)	2,916	(511)	4,374	(766)	4,811	(843)	6,014	(1,053)
114	(2,900)	2,160	(382)	3,078	(539)	4,617	(809)	5,078	(889)	6,348	(1,112)
120	(3,000)	2,280	(400)	3,240	(567)	4,860	(851)	5,346	(936)	6,683	(1,170)
132	(3,400)	2,520	(440)	3,564	(624)	5,340	(935)	5,881	(1,030)	7,351	(1,287)
144	(3,600)	2,740	(480)	3,888	(681)	5,832	(1,021)	6,415	(1,123)	8,019	(1,404)

*Closest customary metric equivalent.

Method 1: Method 1 can be used for pipe sizes up to and including 27 in. (700 mm). In method 1, the pipe shall withstand, without failure, the beam loads listed in Table 12 when tested in accordance with the beam-strength test method of ASTM D3517.

Method 2: Method 2 can be used for all pipe sizes. In method 2, the pipe shall meet or exceed (1) the minimum axial tensile strength listed in Table 11 when tested in accordance with Sec. 5.1.2.4; and (2) the minimum axial compressive strength listed in Table 13 when tested in accordance with ASTM D695.

5.1.2.6 Dimensions. The manufacturer shall inspect one length per 100 lengths of pipe before shipment for dimensions and tolerances outlined in Sec. 4.5.

Sec. 5.2 Rejection and Retesting

If the results of any test do not conform to the requirements of this standard, then that test may be repeated on two additional samples from the same lot of pipe. Each of the two samples shall conform to the requirements specified. If either of the two additional samples fail, the lot may be rejected, at the option of the purchaser. Rejection should be reported to the manufacturer or supplier promptly and in writing.

Table 12 Beam strength requirements

Nominal Pipe Size		Beam Load P	
in.	*(mm)**	*lbf*	*kN*
1	(25)	10	(.04)
1½	(40)	25	(.11)
2	(50)	45	(.20)
2½	(65)	75	(.33)
3	(80)	100	(.44)
4	(100)	185	(.82)
6	(150)	425	(1.9)
8	(200)	800	(3.6)
10	(250)	1,200	(5.3)
12	(300)	1,600	(7.1)
14	(350)	2,200	(9.8)
15	(375)	2,600	(11.6)
16	(400)	3,000	(13.3)
18	(450)	4,000	(17.8)
20	(500)	4,400	(19.6)
21	(550)	5,000	(22.2)
24	(600)	6,400	(28.5)
27	(700)	8,000	(35.6)

*Closest customary metric equivalent.

Table 13 Minimum axial compressive strength requirements

Nominal Pipe Size		Minimum Axial Compressive Strength	
in.	*(mm)*[*]	*lbf/in. of circumference*	*(kN/m of circumference)*
1–6	(25–150)	360	(63)
8–30	(200–800)	580	(102)
33	(850)	640	(111)
36	(900)	700	(122)
39	(1,000)	780	(137)
42	(1,100)	800	(140)
45	(1,150)	860	(150)
48	(1,200)	920	(161)
51	(1,300)	980	(171)
54	(1,400)	1,040	(182)
60	(1,500)	1,140	(200)
66	(1,700)	1,260	(220)
72	(1,800)	1,360	(238)
78	(2,000)	1,480	(260)
84	(2,200)	1,600	(280)
90	(2,300)	1,720	(301)
96	(2,400)	1,840	(322)
102	(2,600)	1,940	(340)
108	(2,800)	2,060	(360)
114	(2,900)	2,180	(382)
120	(3,000)	2,280	(400)
132	(3,400)	2,520	(440)
144	(3,600)	2,740	(480)

*Closest customary metric equivalent

SECTION 6: DELIVERY

Sec. 6.1 Marking

Each standard length and random length shall be clearly marked. Marking shall be applied without indentation so as to remain legible during normal handling and installation practices. At a minimum, these markings shall consist of the following: (1) the phrase *AWWA C950*; (2) nominal pipe size, cell classification, and diameter series; (3) AWWA pressure class; (4) stiffness class; and (5) manufacturer's mark and identity code.

Sec. 6.2 Shipping

All pipe and couplings shall, unless otherwise specified by the purchaser, be prepared for standard commercial shipment.

Sec. 6.3 Affidavit of Compliance

The manufacturer shall, if so specified by the purchaser, provide an affidavit that all delivered materials comply with the requirements of this standard and of the purchaser.

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