



**American Water Works
Association**

ANSI/AWWA C906-07
(Revision of ANSI/AWWA C906-99)

The Authoritative Resource on Safe Water®

AWWA Standard

Polyethylene (PE) Pressure Pipe and Fittings, 4 In. (100 mm) Through 63 In. (1,600 mm), for Water Distribution and Transmission



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AWWA Standard

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C906.

I. Introduction.

I.A. *Background.* This standard describes polyethylene (PE) pressure pipe and fittings in diameters ranging from 4 through 63 in. (100 through 1,600 mm) for use primarily in the construction and rehabilitation of underground water distribution systems.

This document describes pipes and fittings made from PE materials with standard PE code designations PE 2406, PE 3406, and PE 3408. Pipes are classified in accordance with standard pipe dimension ratios (DRs) (i.e., the ratio of pipe outside diameter to pipe minimum wall thickness) that range from 7.3 to 32.5. The resultant combinations of PE material designations and DRs yield pipe with pressure classes (PC) ranging from 40 to 254 psig (276 to 1,750 kPa).

Three standard pipe diameter systems are described, as follows:

- Outside diameters in accordance with the iron pipe size (IPS) system (ANSI B36.10).
- Outside diameters in accordance with the ductile iron sizing system (DIOD) (ANSI/AWWA C110/A21.10).
- Outside diameters in accordance with the International Standards Organization (ISO) sizing system (ISO 161/1).

However, this standard also includes provision for specifying pipe with custom diameters and diameter ratios.

I.B. *History.* In 1984, the Standards Committee on Thermoplastic Pressure Pipe appointed a subcommittee to prepare a standard covering 4 in. (100 mm) and larger diameter polyethylene (PE) pressure pipe and fittings. The first proposed draft was submitted to the Thermoplastic Pressure Pipe Committee by letter ballot in May 1986.

The Thermoplastic Pressure Pipe Committee was subsequently dissolved, and its standards responsibilities were divided between two new AWWA standards committees—the PVC Pressure Pipe and Fittings Committee and the Polyolefin Pressure Pipe and Fittings Committee. The Polyolefin Pressure Pipe and Fittings Committee assumed the responsibility for developing this standard in the fall of 1988. The first edition of C906 was approved by the AWWA Board of Directors on June 21, 1990,

and the second edition was approved on June 20, 1999. This edition was approved Jan. 21, 2007.

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 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: NSF[†]/ANSI[‡] 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 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 NSF/ANSI 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.

*Persons outside the US should contact the appropriate authority having jurisdiction.

†NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48113.

‡American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

§Both publications available from National Academy of Sciences, 500 Fifth Street, N.W., Washington, DC 20418.

Annex A, “Toxicology Review and Evaluation Procedures,” to NSF/ANSI 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 C906 does not address additives requirements (i.e., substances that can be extracted from the pipe by flowing potable water). 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 parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues.

II.A. *Advisory Information on Product Application.* This standard presents criteria related to the manufacture and purchase of polyethylene pressure pipe to be used in the transmission of potable water in either buried or aboveground applications. Pipe provided according to the provisions of this standard may also be suitable for insertion into existing pipelines for rehabilitation and for the transmission of other liquids.

This standard restricts the materials used for the manufacture of polyethylene pipe to three standard PE code designations: PE 2406, PE 3406, and PE 3408. These three materials provide two series of pressure class ratings, one for PE 2406 or PE 3406 material and one for PE 3408 material. This standard describes 10 dimension ratios for nominal pipe sizes ranging from 4 in. (100 mm) through 63 in. (1,600 mm). Actual outside pipe diameters conform to the outside diameter dimensions of iron pipe sizes (IPS), ductile-iron pipe sizes (DIOD), or to those outside diameters established by the International Organization for Standardization (ISO).

Although this standard generally presents adequate information for ordering pipe that meets project working pressure requirements, it does not include information to guide the designer in the determination of wall thicknesses, pipe flexibility requirements, and installation conditions to meet external loading conditions. The AWWA manual M55: *PE Pipe Design and Installation* provides this information. In addition, consultation with PE pipe manufacturers is recommended.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. Purchaser Options and Alternatives. Some items in this standard are optional requiring identification of the selected option(s) such as material type, color, and size. When specifying products described in this standard, the purchaser should provide specific information regarding the following:

1. Standard used—that is, ANSI/AWWA C906, Standard for Polyethylene (PE) Pressure Pipe and Fittings, 4 In. (100 mm) Through 63 In. (1,600 mm), for Water Distribution and Transmission, of latest edition.

2. Whether compliance with NSF/ANSI 61 Drinking Water System Components—Health Effects, is required, in addition to the requirements of the Safe Drinking Water Act.

3. Details of other federal, state, local, and provincial requirements (Sec. 4.2.1).

4. Pipe.

a. Standard code designation of the PE material (Sec. 4.2.1 and Table 1).

b. Color or color coding.

c. Nominal size, outside diameter base (IPS, DIOD, or ISO), dimension ratio (DR), and pressure class (PC); length of individual pieces, and total linear feet for each different item to be provided. For special sizes, the purchaser should establish, in consultation with the pipe manufacturer, the actual outside diameter, the actual dimension ratio, and the actual wall thickness.

5. Fittings.

a. Standard code designation of the PE material (Sec. 4.2.1 and Table 1).

b. Description of fitting (e.g., tee, elbow, and so forth), nominal size(s) at point of fusion, whether molded or fabricated, and pressure class (PC).

6. Fusion conditions. To ensure optimum efficiency of fusion when joining the product(s) being purchased, the purchaser should request from the manufacturer a list of the recommended fusion parameters, and documentation that these parameters have been validated by appropriate testing. If the purchased piping is to be fused with existing PE piping, the purchaser should inform the manufacturer of the cell classifi-

cation of the existing PE pipe (see Table 1 and ASTM* D3350), and obtain from the manufacturer a list of the validated fusion parameters that may be used to join the purchased piping to the existing piping.

7. Additional requirements. The following requirements may also be specified in the purchase contract:

- a. Special quality-assurance testing (Sec. 5).
- b. Plant inspection by purchaser (Sec. 5).
- c. Special markings (Sec. 6.1).
- d. Shipping (Sec. 6.2).
- e. Affidavit of compliance (Sec. 6.3).

III.B. *Modification of Standard.* Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. **Major Revisions.** Major changes made to the standard in this revision include the following:

1. Materials language has been added (Sec. III.A.2 and Sec. 4.2.1).
2. Design and installation materials have been deleted from the standard as they are now covered in AWWA M55 (Sec. 2, 4.5.2, 4.5.3, 4.5.4, and 4.5.5).
3. Design information not yet incorporated in AWWA M55 has been moved from Sec. 4.6.2 to appendix B.

V. **Comments.** If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group at 303.794.7711, FAX 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail standards@awwa.org.

*ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

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AWWA Standard

Polyethylene (PE) Pressure Pipe and Fittings, 4 In. (100 mm) Through 63 In. (1,600 mm), for Water Distribution and Transmission

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes polyethylene (PE) pressure pipe made from materials conforming to standard PE code designations PE 2406, PE 3406, and PE 3408. The pipe is primarily intended for use in transporting potable water in either buried or aboveground installations. The standard describes 10 dimension ratios (DRs) for nominal pipe sizes ranging from 4 in. (100 mm) through 63 in. (1,600 mm). Pipe outside diameters (ODs) conform to the outside diameter dimensions of iron pipe (OD-based, IPS), to those established by the International Organization for Standardization (ISO), or to those established for DI equivalent ODs (DIOD).

Pressure classes range from 40 psi (276 kPa) to 198 psi (1,365 kPa) for both PE 2406 and PE 3406 materials, and from 51 psi (352 kPa) to 254 psi (1,751 kPa) for PE 3408 material.

Sec. 1.2 Purpose

The purpose of this standard is to provide purchasers, manufacturers, and suppliers with the minimum requirements for PE pressure pipe and fittings, 4 in. (100 mm) through 63 in. (1,600 mm), for water distribution and transmission.

Sec. 1.3 Application

This standard can be referenced for purchasing and receiving PE pressure pipe and fittings, 4 in. (100 mm) through 63 in. (1,600 mm), for water distribution and transmission. The stipulations of this standard apply when this document has been referenced and then only to PE pressure pipe and fittings, 4 in. (100 mm) through 63 in. (1,600 mm), for water distribution and transmission.

SECTION 2: REFERENCES

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

ANSI*/AWWA C111/A21.11—ANSI Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Fittings.

ANSI/AWWA C150/A21.50—ANSI Standard for Thickness Design of Ductile-Iron Pipe.

ANSI/AWWA C207—Steel Pipe Flanges for Waterworks Service—Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm).

ANSI B16.1—Cast Iron Pipe Flanges and Flanged Fittings.

ANSI B16.47—Large Diameter Steel Flanges: NPS 26 Through NPS 60.

ANSI B16.5—Pipe Flanges and Flanged Fittings.

ANSI B36.10—Welded and Seamless Wrought Steel Pipe.

ASTM D618—Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing.

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

ASTM D1238—Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.

*American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.

ASTM D1598—Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure.

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

ASTM D1603—Standard Test Method for Carbon Black in Olefin Plastics.

ASTM D2122—Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings.

ASTM D2290—Standard Test Method for Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method.

ASTM D2657—Standard Specification for Heat Fusion Joining of Polyolefin Pipe and Fittings.

ASTM D2683—Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing.

ASTM D2837—Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.

ASTM D2839—Standard Test Method for Use of a Melt Index Strand for Determining Density of Polyethylene.

ASTM D3261—Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.

ASTM D3350—Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.

ASTM D4218—Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.

ASTM F412—Standard Terminology Relating to Plastic Piping Systems.

ASTM F1055—Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing.

AWWA Manual M55, PE Pipe—Design and Installation.

ISO 161/1—Thermoplastics Pipes for the Conveyance of Fluids—Nominal Outside Diameters and Nominal Pressures—Part 1 Metric Series.

PPI* TR-3—Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials.

AWWA Standards Committee Report on Design and Installation of Polyethylene Pipe in accordance with ANSI/AWWA C906.

*The Plastics Pipe Institute, 1825 Connecticut Avenue N.W., Suite 680, Washington, DC 20009.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

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

2. *Design factor (DF)*: The factor that is used to reduce the hydrostatic design basis (HDB) to arrive at the hydrostatic design stress (HDS) from which the pressure class (PC) is calculated. Unless otherwise noted, the design factor used in this standard is 0.5.

NOTE: Because the effective strength of PE materials depends on the duration of stress application and temperature, the effective safety factor when using a DF of 0.5 will vary with end-use conditions. For the PE materials described in this standard, the effective safety factor against transient and sustained pressures is at least 2:1. The actual value is generally larger and depends on the magnitude of the applied transient and sustained pressures, as well as on the operating temperature.

3. *Dimension ratio (DR)*: The ratio of a pipe's specified outside diameter to its specified minimum wall thickness.

The average specified outside diameter is used for establishing pipe DR using inch-pound units. With metric units, the minimum specified outside diameter is used.

4. *Hydrostatic design basis (HDB)*: The categorized long-term strength in the circumferential or hoop direction as established from long-term pressure tests in accordance with PPI TR-3 and the methodology contained in ASTM D2837.

5. *Hydrostatic design stress (HDS)*: The maximum allowable working hoop stress in the pipe wall when the pipe is subjected to sustained long-term hydrostatic pressure. The HDS in this standard is established by multiplying the HDB by the design factor (DF), 0.5, for water applications.

6. *Lot*: A shipment of resin material that is included under one material certification.

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

8. *Polyethylene plastics*: Thermoplastic extrusion and molding materials prepared by polymerization of no less than 85 percent ethylene and no less than 95 percent of total olefins by weight, plus the addition of compounding ingredients.

9. *Pressure class (PC)*: The pressure class is the design capacity able to resist working pressure up to 80°F (27°C) service temperature with specified allowances for recurring positive surge pressure above working pressure. These allowances and the methods for determining pressure class are stated in Sec. 4.6.

10. *Production run*: The length of time a particular piece of extrusion equipment is set up to produce a certain size of pipe.

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

12. *Standard dimension ratio (SDR)*: A DR that corresponds to one of the numbers in the standard series of preferred dimension ratios that has been established by the American Society for Testing and Materials (ASTM F412).

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

14. *Surge pressure (P_S)*: The maximum pressure increase and decrease that is anticipated in a system as the result of a sudden change in the velocity of the water. Surge pressure is sometimes called water hammer. Two types of surge pressure must be considered for product selection and system design:

a. *Recurring surge pressure (P_{RS})*: Recurring surge pressures occur frequently and are inherent to the design and operation of the system (such as normal pump startup or shutdown, and normal valve opening or closure).

b. *Occasional surge pressure (P_{OS})*: Occasional surge pressures are caused by emergency operations. Occasional surge pressure is usually the result of a fire flow or a malfunction, such as a power failure or system component failure, which includes pump seize-up, valve-stem failure, and pressure-relief-valve failure.

Note: Surge pressure caused by emergency pump and valve operations are usually severe. The system should be designed to withstand positive and negative pressures caused by these emergency operations. Water column separation may occur if the negative pressure is reduced to the vapor pressure of the liquid. Rejoining of the separated water column typically results in a large pressure rise, which will probably damage the pipe system. Whenever possible, water column separation should be avoided.

15. *Working pressure (WP)*: The maximum anticipated, sustained operating pressure applied to the pipe exclusive of transient pressures.

16. *Working pressure rating (WPR)*: The working pressure rating is the design capacity to resist working pressure at the anticipated operating temperature, with

sufficient capacity against the actual anticipated positive surge pressure above working pressure. A pipe's WPR may be equal to or less than its nominal PC, depending on the positive transient pressure characteristics of the system and pipe operating temperature if above 80°F (27°C). The method for determining WPR is stated in Sec. 4.6.2.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution piping in locations where 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 used in jointing gaskets and packing glands, are subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through a contaminated area or an area subject to contamination, consult with pipe manufacturers regarding permeation of pipe walls, jointing materials, etc., *before* selecting materials for use in that area.

Sec. 4.2 Materials

4.2.1 *Materials.* Materials shall comply with the requirements of the Safe Drinking Water Act and other federal requirements.

4.2.2 *General.* This standard describes PE pipe, fittings, and joints made from PE materials with one of the standard PE code designations as listed in Table 1. PE material code designations shall be established in accordance with ASTM D3350 and ASTM D2837. The hydrostatic design basis (HDB) of the PE materials shall be established in accordance with PPI TR-3.

Table 1 PE pipe and fittings materials

Standard PE Code Designation	PE Material, Minimum Cell Classification* ASTM D3350	Hydrostatic Design Basis at 73.4°F (23° C) ASTM D2837
PE 2406	PE 213333C, D, or E	1,250 psi (8.62 MPa)
PE 3406	PE 324433C, D, or E	1,250 psi (8.62 MPa)
PE 3408	PE 334434C, D, or E	1,600 psi (11.03 MPa)

*The cell classification number is determined by testing in accordance with ASTM D3350. The second through fifth digits of the cell classification number given in Table 1 represent the minimum cell classification for the standard PE code designation listed. The cell number may be higher for a given PE code designation.

4.2.3 *Composition.* PE pipe materials shall contain at least 2 percent finely divided and well-dispersed carbon black. Colored products shall contain sufficient UV stabilizer (in lieu of carbon black) for 24 months of outdoor storage. Sufficient antioxidant must be added to ensure that production pipe meets the thermal stability requirements of Sec. 4.3.4.

4.2.4 *Rework materials.* Clean rework materials derived from a manufacturer's own pipe or fitting product may be used by the same manufacturer for similar purposes provided that (1) the cell classification of the rework material is identical with the material to which it will be added; (2) the rework material complies with applicable requirements of Sec. 4.2 of this standard; and (3) the finished products meet the requirements specified by the purchaser and comply with requirements of this standard.

4.2.5 *Qualification for potable water service.* The PE materials used to make pipe and fittings shall contain no ingredient in an amount that has been demonstrated to migrate into water in quantities that are considered to be detrimental to the water quality.*

4.2.6 *Elevated-temperature sustained-pressure test.* The PE pipe materials shall meet the requirements listed in Table 2 when the material is tested in accordance with ASTM D1598 at the stress given in Table 2 and using $176 \pm 3.6^\circ\text{F}$ ($80 \pm 2^\circ\text{C}$) water as the pressurizing and external media.

*See foreword, Sec. I.C.

Table 2 Elevated-temperature [176 ± 3.6°F (80 ± 2°C)] sustained-pressure test

Base Resin Density (<i>gm/cc</i>)	Minimum Average Failure Time (<i>h</i>)*	
	S=580 <i>psi</i> (4 <i>MPa</i>)	S=670 <i>psi</i> (4.6 <i>MPa</i>)
>0.935	1,000	170

*Test a minimum of three specimens at one of the two defined hoop stress levels. The average failure time must meet or exceed the specified minimum average failure time, and no less than two out of the three specimens shall meet or exceed the specified minimum average failure time. The test pressure (P) may be computed from the test hoop stress and pipe dimensions by means of the following equation:

$$P = \frac{2St}{(OD - t)} = \frac{2S}{(DR - 1)}$$

Where: P = test pressure, *psi* (*MPa*).

S = test hoop stress from Table 2, *psi* (*MPa*).

t = actual minimum wall thickness, *in.* (*mm*).

OD = actual average outside diameter, *in.* (*mm*), for products using the IPS and DIOD sizing system. OD is the minimum allowable outside diameter in *in.* (*mm*) for products using the ISO sizing system.

DR = Dimension ratio = OD/ t .

4.2.7 *Colored materials.* The use of solid-color (nonblack) or color-striped pipe is allowed. The color compound incorporated with the pipe material shall meet the requirements of this standard.

Sec. 4.3 Pipe Requirements

4.3.1 *Workmanship.* Pipe shall be homogeneous and as uniform as commercially practical. Colored coextrusions and pipe striping are allowed according to other provisions of the standard. The inside and outside surfaces shall be semimatte to glossy in appearance and free from sticky or tacky material. The pipe walls shall be free of cuts, cracks, holes, blisters, voids, foreign inclusions, or other defects that are visible to the naked eye and that may affect the wall integrity.

4.3.2 *Dimensions and tolerances.* Pipe shall conform to the applicable dimension requirements specified in Tables 3 through 8 of this standard and to any other dimensional requirements stipulated in the applicable standards referenced in Section 2. Measurements shall be made according to the methods specified in ASTM D2122.

4.3.2.1 *Wall thickness variability.* Wall thickness variability as measured and calculated according to ASTM D2122 in any diametrical cross section of the pipe

shall not exceed 12 percent.

4.3.3 *Special sizes.* When agreed on by the manufacturer and the purchaser, other diameters and wall thicknesses shall be considered acceptable if the pipe and fittings meet the following requirements:

1. The product shall be made from only the materials listed within this standard.
2. Pressure class and test requirements shall be established on the same basis as that used by this standard for the listed diameters and wall thicknesses.
3. The dimensional tolerances for diameter and wall thickness shall be the same tolerance on a percentage basis as that specified for the average outside diameter and minimum wall thickness for the next smaller size.

4.3.4 *Thermal stability.* A specimen taken from the midwall area of production pipe shall be tested for thermal stability in accordance with ASTM D3350 Sec. 10.1.9, Thermal Stability. The minimum induction temperature measured by this method shall be 428°F (220°C).

4.3.5 *Ring-tensile strength test.* Specimens shall be cleanly cut from the pipe and tested in accordance with ASTM D2290. The tensile strength shall be not less than 2,500 psi (17.2 MPa) for pipe made from PE 2406 material and not less than 2,900 psi (20.0 MPa) for pipe made from PE 3406 and PE 3408 materials.

Table 3 Outside diameters (ODs) and tolerances* IPS sizing system (ANSI B36.10)

Nominal IPS Pipe Size	Outside Diameter (OD)			
	Average		Tolerance	
	<i>in.</i>	<i>(mm)</i>	<i>in.</i>	<i>(mm)</i>
4.0	4.500	(114.3)	±0.020	(±0.51)
5.0	5.563	(141.3)	±0.025	(±0.64)
6.0	6.625	(168.3)	±0.030	(±0.76)
7.0 [†]	7.125	(181.0)	±0.034	(±0.86)
8.0	8.625	(219.1)	±0.039	(±0.99)
10.0	10.75	(273.1)	±0.048	(±1.22)
12.0	12.75	(323.8)	±0.057	(±1.45)
13.0	13.375	(339.7)	±0.060	(±1.52)
14.0	14.000	(355.6)	±0.063	(±1.60)
16.0	16.000	(406.4)	±0.072	(±1.80)
18.0	18.000	(457.2)	±0.081	(±2.06)
20.0	20.000	(508.0)	±0.090	(±2.29)
21.5 [†]	21.500	(546.1)	±0.097	(±2.46)
22.0	22.000	(558.8)	±0.099	(±2.51)
24.0	24.000	(609.6)	±0.108	(±2.74)
26.0	26.000	(660.4)	±0.117	(±2.97)
28.0	28.000	(711.2)	±0.126	(±3.20)
32.0	32.000	(812.8)	±0.144	(±3.66)
34.0	34.000	(863.6)	±0.153	(±3.89)
36.0	36.000	(914.4)	±0.162	(±4.11)
42.0	42.000	(1,066.8)	±0.189	(±4.80)
48.0	48.000	(1,219.2)	±0.243	(±6.17)
54.0	54.000	(1,371.6)	±0.284	(±7.20)
63.0	63.000	(1,600.2)	±0.284	(±7.20)

*See Sec. 4.3.3 for provisions for additional sizes and tolerances.

[†]Special outside diameters not included in ANSI B36.10.

Table 4 Minimum wall thicknesses (in.), IPS sizing system

Nominal IPS Pipe Size (OD)	Dimension Ratio									
	32.5*	26.0*	21.0*	17.0*	15.5	13.5*	11.0*	9.3*	9.0*	7.3*
4.0	0.138	0.173	0.214	0.265	0.290	0.333	0.409	0.482	0.500	0.616
5.0	0.171	0.214	0.265	0.327	0.359	0.412	0.506	0.598	0.618	0.762
6.0	0.204	0.255	0.316	0.390	0.427	0.491	0.602	0.710	0.736	0.908
7.0†	0.220	0.274	0.340	0.420	0.460	0.528	0.648	0.766	0.792	0.976
8.0	0.265	0.332	0.411	0.507	0.556	0.639	0.784	0.927	0.958	1.182
10.0	0.331	0.413	0.512	0.632	0.694	0.796	0.977	1.156	1.194	1.473
12.0	0.392	0.490	0.607	0.750	0.823	0.944	1.159	1.371	1.417	1.747
13.0†	0.412	0.515	0.638	0.788	0.863	0.991	1.216	1.438	1.486	1.832
14.0	0.431	0.538	0.667	0.824	0.903	1.037	1.273	1.505	1.556	1.918
16.0	0.492	0.615	0.762	0.941	1.032	1.185	1.455	1.720	1.778	2.192
18.0	0.554	0.692	0.857	1.059	1.161	1.333	1.636	1.935	2.000	2.466
20.0	0.615	0.769	0.952	1.176	1.290	1.481	1.818	2.151	2.222	2.740
21.5†	0.662	0.827	1.024	1.265	1.387	1.593	1.955	2.312	2.389	2.945
22.0	0.677	0.846	1.048	1.294	1.419	1.630	2.000	2.366	2.444	3.014‡
24.0	0.738	0.923	1.143	1.412	1.548	1.778	2.182	2.581	2.667	3.288
26.0	0.800	1.000	1.238	1.529	1.677	1.926	2.364	2.796	2.889	3.562
28.0	0.862	1.077	1.333	1.647	1.806	2.074	2.545	3.011‡	3.111‡	3.836
30.0	0.923	1.154	1.429	1.765	1.935	2.222	2.727	3.226	3.333	4.110
32.0	0.985	1.231	1.524	1.882	2.065	2.370	2.909	3.441	3.556	4.384
34.0	1.046	1.308	1.619	2.000	2.194	2.519	3.091‡	3.656	3.778	4.658
36.0	1.108	1.385	1.714	2.118	2.323	2.667	3.273	3.871	4.000	4.932
42.0	1.292	1.615	2.000	2.471	2.710	3.111‡	3.818	4.516	4.667	5.753
48.0	1.477	1.846	2.286	2.824	3.097‡	3.556	4.364	5.161	5.333	6.575
54.0	1.662	2.077	2.571	3.177‡	3.484	4.000	4.909	5.807	6.000	7.397
63.0	1.938	2.423	3.000	3.706	4.065	4.667	5.727	6.774	7.000	8.630

NOTE: Average inside diameter (ID) can be calculated as follows: Average ID = Nominal OD - 2 ($t_{\min} \times 1.06$).

*These DRs are from the standard dimension ratio (SDR) series established by ASTM (see ASTM F412).

†Special sizes.

‡For wall thicknesses greater than 3 in., consult individual pipe manufacturers for capabilities.

Table 5 DI: Outside diameters (ODs) and tolerances* for ductile-iron sizing system (DIOD)

Nominal DIOD Pipe Size (<i>in.</i>)	Outside Diameter, OD			
	Average		Tolerance	
	<i>in.</i>	(<i>mm</i>)	<i>in.</i>	(<i>mm</i>)
4	4.800	(121.9)	0.022	(0.55)
6	6.900	(175.3)	0.031	(0.79)
8	9.050	(229.9)	0.041	(1.03)
10	11.100	(281.9)	0.050	(1.27)
12	13.200	(335.3)	0.059	(1.51)
14	15.300	(388.6)	0.069	(1.75)
16	17.400	(442.0)	0.078	(1.99)
18	19.500	(495.3)	0.088	(2.23)
20	21.600	(548.6)	0.097	(2.47)
24	25.800	(655.3)	0.116	(2.95)
30	32.000	(812.8)	0.144	(3.66)
36	38.300	(972.8)	0.172	(4.38)
42	44.500	(1,130.3)	0.200	(5.09)
48	50.800	(1,290.3)	0.229	(5.81)
54	57.100	(1,450.3)	0.257	(6.53)

*See Sec. 4.3.3 for provisions for additional sizes and tolerances.

Table 6 DI: Minimum wall thicknesses (in.) for ductile-iron sizing system (DIOD)

Nominal DIOD Pipe Size (OD)	Average* OD (in.)	Dimension Ratio [†]									
		32.5	26	21	17	15.5	13.5	11	9.3	9	7.3
4	4.800	0.148	0.185	0.229	0.282	0.310	0.356	0.436	0.516	0.533	0.658
6	6.900	0.212	0.265	0.329	0.406	0.445	0.511	0.627	0.742	0.767	0.945
8	9.050	0.278	0.348	0.431	0.532	0.584	0.670	0.823	0.973	1.006	1.240
10	11.100	0.342	0.427	0.529	0.653	0.716	0.822	1.009	1.194	1.233	1.521
12	13.200	0.406	0.508	0.629	0.776	0.852	0.978	1.200	1.419	1.467	1.808
14	15.300	0.471	0.588	0.729	0.900	0.987	1.133	1.391	1.645	1.700	2.096
16	17.400	0.535	0.669	0.829	1.024	1.123	1.289	1.582	1.871	1.933	2.384
18	19.500	0.600	0.750	0.929	1.147	1.258	1.444	1.773	2.097	2.167	2.671
20	21.600	0.665	0.831	1.029	1.271	1.394	1.600	1.964	2.323	2.400	2.959
24	25.800	0.794	0.992	1.229	1.518	1.665	1.911	2.345	2.774	2.867	3.534 [‡]
30	32.000	0.985	1.231	1.524	1.882	2.065	2.370	2.909	3.441 [‡]	3.556 [‡]	4.384
36	38.300	1.178	1.473	1.824	2.253	2.471	2.837	3.482 [‡]	4.118	4.256	5.247
42	44.500	1.369	1.712	2.119	2.618	2.871	3.296 [‡]	4.046	4.785	4.944	6.096
48	50.800	1.563	1.954	2.419	2.988	3.277 [‡]	3.763	4.618	5.462	5.644	6.959
54	57.100	1.757	2.196	2.719	3.359 [‡]	3.684	4.230	5.191	6.140	6.344	7.822

*Average ID can be calculated as follows: Average ID = Nominal OD–2 ($t_{\min} \times 1.06$).

[†]All DRs are from the standard dimension ratio (SDR) series established by ASTM (see ASTM F412) except for SDR 15.5 and SDR 9.3.

[‡]Consult individual manufacturers for production capabilities for wall thicknesses above 3 in.

Table 7 Outside diameters and tolerances*, metric sizing system (ISO 161/1)

Nominal Metric Pipe Size	Outside Diameter, OD		Equivalent Outside Diameter, OD	
	OD Minimum	OD Maximum	OD Minimum	OD Maximum
	<i>mm</i>	<i>mm</i>	<i>in.</i>	<i>in.</i>
110	110	111.0	4.331	4.370
160	160	161.4	6.299	6.354
200	200	201.8	7.874	7.945
250	250	252.3	9.843	9.933
280	280	282.5	11.024	11.122
315	315	317.8	12.402	12.512
355	355	358.2	13.976	14.102
400	400	403.6	15.748	15.890
450	450	454.1	17.717	17.878
500	500	504.5	19.685	19.862
560	560	565.0	22.047	22.244
630	630	636.7	24.803	25.028
710	710	716.4	27.953	28.205
800	800	807.2	31.496	31.800
900	900	908.1	35.433	35.752
1,000	1,000	1,009.0	39.370	39.724
1,200	1,200	1,210.8	47.244	47.669
1,400	1,400	1,412.6	55.118	55.614
1,600	1,600	1,614.4	62.992	63.559

*See Sec. 4.3.3 for provisions for additional sizes and tolerances.

Table 8 Minimum wall thicknesses* (mm), metric sizing system

Nominal Metric Pipe Size (OD)	Dimension Ratio									
	32.5 [†]	26.0 [†]	21.0 [†]	17.0 [†]	15.5	13.5 [†]	11.0 [†]	9.3	9.0 [†]	7.3 [†]
110	3.4	4.2	5.2	6.5	7.1	8.1	10.0	11.8	12.2	15.1
160	4.9	6.2	7.6	9.4	10.3	11.9	14.5	17.2	17.8	21.9
200	6.2	7.7	9.5	11.8	12.9	14.8	18.2	21.5	22.2	27.4
250	7.7	9.6	11.9	14.7	16.1	18.5	22.7	26.9	27.8	34.2
280	8.6	10.8	13.3	16.5	18.1	20.7	25.5	30.1	31.1	38.4
315	9.7	12.1	15.0	18.5	20.3	23.3	28.6	33.9	35.0	43.2
355	10.9	13.7	16.9	20.9	22.9	26.3	32.3	38.2	39.4	48.6
400	12.3	15.4	19.0	23.5	25.8	29.6	36.4	43.0	44.4	54.8
450	13.8	17.3	21.4	26.5	29.0	33.3	40.9	48.4	50.0	61.6
500	15.4	19.2	23.8	29.4	32.3	37.0	45.5	53.8	55.6	68.5
560	17.2	21.5	26.7	32.9	36.1	41.5	50.9	60.2	62.2	76.7 [‡]
630	19.4	24.2	30.0	37.1	40.6	46.7	57.3	67.7	70.0	86.3
710	21.8	27.7	33.8	41.8	45.8	52.6	64.5	76.3 [‡]	78.9 [‡]	97.3
800	24.6	30.8	38.1	47.1	51.6	59.3	72.7	86.0	88.9	109.6
900	27.7	34.6	42.9	52.9	58.1	66.7	81.8 [‡]	96.8	100.0	123.3
1,000	30.8	38.5	47.6	58.8	64.5	74.1	90.9	107.5	111.1	137.0
1,200	36.9	46.2	56.1	70.6	77.4 [‡]	88.9 [‡]	109.1	129.0	133.3	164.4
1,400	43.1	53.8	66.7	82.4 [‡]	90.3	103.7	127.3	150.5	155.6	191.8
1,600	49.2	61.5	76.2 [‡]	94.1	103.2	118.5	145.5	172.0	177.8	219.2

*Minimum wall thicknesses calculated using minimum outside diameters.

[†]These DRs are from the standard dimension ratio (SDR) series established by ASTM F412

[‡]For wall thicknesses above 75 mm, consult individual pipe manufacturers for capabilities.

NOTE: Average inside diameter (ID) can be calculated as follows:

$$\text{Avg ID} = \frac{\text{OD}_{\min} + \text{OD}_{\max}}{2} - 2(t_{\min} \times 1.06)$$

4.3.6 *Quick-burst test.* Specimens shall be cleanly cut from the pipe and tested in accordance with ASTM D1599. The test pressure at failure shall not be less than that which results from a minimum hoop stress value of 2,500 psi (17.2 MPa) for PE 2406 materials. For PE 3406 and PE 3408 materials, the minimum hoop stress value shall be 2,900 psi (20.0 MPa). Hoop stress values shall be based on the initial (prior to test) dimensions of the specimens.

4.3.7 *Bend-back test.* Specimens shall be taken from the pipe and tested in accordance with the test method described in Sec. 5.7. The inner surface of the pipe shall give no indications of brittle-like cracking or crazing when examined with the naked eye.

4.3.8 *Elongation-at-break test.* Five specimens cut equally spaced around the circumference of the pipe in the longitudinal direction shall be prepared and tested in accordance with ASTM D638 using a cross-head separation speed of 2 in. (50.8 mm) per minute. If the sample thickness must be reduced by milling, the inside surface of the pipe shall be left unaltered. The elongation at break for each test specimen shall exceed 400 percent.

4.3.9 *Five-second pressure test.* A section of pipe shall be prepared and tested in accordance with test method ASTM D1598. The pipe shall not burst, crack, split, or otherwise fail a test pressure of four times the pipe PC applied for five seconds.

4.3.10 *UV stabilization.* For black product (see Sec. 4.2.2), carbon-black content shall be verified to be at least two percent and not more than three percent by weight when tested in accordance with ASTM D1603 or D4218.

The quantity of UV stabilizer shall be verified to confirm that it meets the manufacturer's specifications. The stabilizer content shall be verified either by direct analytical measurement or by verification of the blend percentages.

4.3.11 *Melt index.* Specimens taken from the pipe shall be tested in accordance with ASTM D1238. Maximum determined values shall conform to those established by the manufacturer based on the manufacturer's extrusion practices and the particular PE material used.

4.3.12 *Density.* Specimens taken from the pipe shall be prepared and tested according to ASTM D2839. Values for this test should be established by the manufacturer based on the manufacturer's extrusion practices and the PE material being used.

4.3.13 *Pipe ends and lengths.* Pipe shall be provided with squarely cut plain ends in lengths and tolerances agreed on by the manufacturer or supplier and the purchaser.

4.3.14 *Toe-in.* The OD, when measured in accordance with ASTM D2122 at the cut-end of the pipe length, shall not be more than 1.5 percent smaller than the average OD specified in Tables 3 through 8 when measured at any point not closer than 12 in. (300 mm) to the squarely cut end of the pipe length.

Sec. 4.4 Fusion Fittings Requirements

4.4.1 *General.* Fittings described by this standard include fittings intended to be joined to PE pipe by thermal fusion. PE fittings may be designed to connect to other types of pipe by mechanical methods, such as compression or flange, to other piping (Figure 1).^{*} Polyethylene fittings may be molded, thermoformed from pipe sections, or fabricated by heat fusion joining polyethylene components prepared from pipe, molded fittings, thermoformed pipe, or polyethylene sheet or block. Molded fittings shall meet the requirements of this standard and the requirements of ASTM D2683 for socket-type fittings, ASTM D3261 for butt-type fittings, or ASTM F1055 for electrofusion-type fittings.

4.4.2 *Workmanship.* Fittings shall be homogeneous throughout and as uniform in color, opacity, density, and other properties as commercially practical. Co-extrusions and pipe striping are allowed. The inside and outside surfaces shall be semimatte to glossy in appearance and free of sticky or tacky material. The walls shall be free of cuts, cracks, holes, blisters, voids, foreign inclusions, or other defects that are visible to the naked eye and that may affect the wall integrity.

^{*}Backup rings (see Figure 1) shall be made of suitable material such as steel, ductile iron, stainless steel, fiberglass, etc. Backup rings shall be provided in accordance with the purchaser's specifications. Vital dimensions shall conform to national standards (ANSI B16.5, ANSI B16.1, ANSI B16.47, and ANSI/AWWA C207) to ensure that they mate with other pipe components. The flange thickness shall be determined by calculation, because no standard currently provides reliable pressure ratings for flanges installed on thermoplastic pipe. The flange thickness shall be supported by calculations based on a safety factor agreed on by the purchaser and the supplier. The purchaser may require that the supplier supply the calculations.

The pressure ratings displayed in ANSI/AWWA C207 apply only when the flanges are welded to steel pipe in a typical slip-on fashion. These pressure ratings do not apply to loose or floating backup flanges on thermoplastic piping stub ends.

Do not assume pressure rating correctness from ANSI/AWWA C207 tables; they do not apply to PE piping systems.

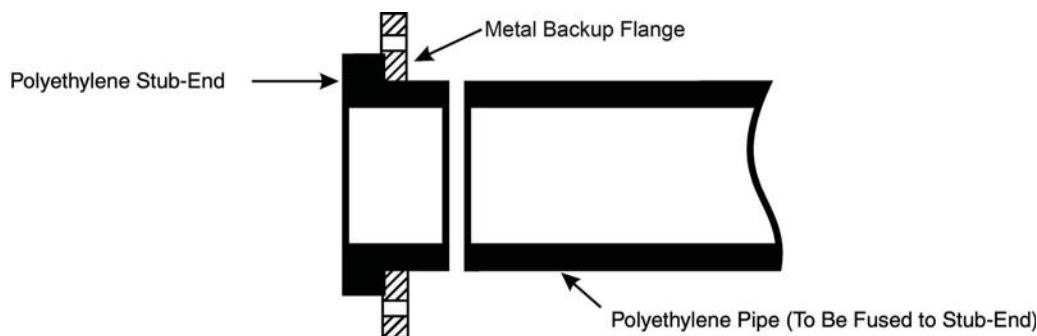


Figure 1 Cross section of polyethylene flange assembly

4.4.3 *Dimensions and tolerances.* Molded fittings shall conform with the dimensional requirements described in the applicable ASTM fitting standard referenced in Section 2 when measured as specified in that standard. Fabricated fittings shall meet the minimum dimensional requirements and tolerances of the pipe at the point of fusion.

4.4.4 *Physical requirements.* Each PE fitting shall meet the material requirements of the pipe to which the fitting will be joined. A fitting fabricated from pipe shall be manufactured from pipe with a wall thickness at least 25 percent greater than the pipe to which the fitting will be joined, or the fitting shall be equal to or greater than the pressure class of the pipe to which the fitting will be joined. Each fitting shall be designed and manufactured to operate at not less than the design pressure of the pipe system for which it is intended. The fitting shall meet the five-second pressure test (Sec. 4.3.9) using the test frequency defined in Sec. 5.5.

Sec. 4.5 Joining Methods

4.5.1 *General.* Polyethylene piping described in this standard may be joined by thermal butt fusion, socket fusion, electrofusion, flange assemblies, or mechanical methods (Figure 2). Polyethylene piping shall not be joined by solvent cements, adhesives (such as epoxies), or threaded-type connections. Joining methods shall be capable of conveying water at the design pressure of the piping system. In situations where different kinds of polyethylene piping materials must be joined to each other, the manufacturers of the subject pipe or fitting should be consulted to determine the appropriate fusion procedures. Joining methods are discussed in detail in AWWA Manual M55.

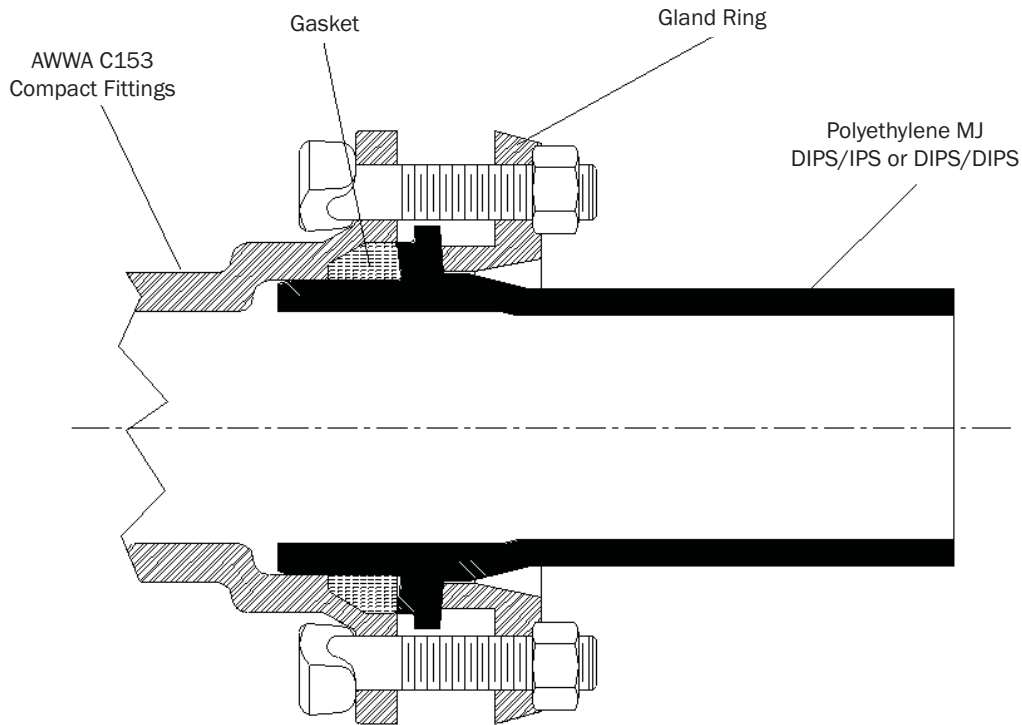


Figure 2 Mechanical joint adapter

Sec. 4.6 Pipe Classification and Working Pressure Rating

4.6.1 *Pressure class.* This standard classifies pipe in accordance with its pressure class (PC). The following expression, commonly known as the ISO (International Organization for Standardization) equation,^{*} is used to calculate the pressure class:

$$PC = \frac{2}{DR - 1} \times HDB \times DF \quad (\text{Eq 1})$$

Where:

PC = pressure class, in psi gauge (kPa gauge)

DR = dimension ratio = OD/t

^{*}ISO R161, Pipe of Plastic Materials for the Transport of Fluids, Part 1, Metric Series.

HDB = hydrostatic design basis for water, 73.4°F (23°C), in psi (kPa) per Table 9

DF = 0.5; design factor; includes consideration of degree of safety and other variables, including limited surge pressure effects, in the end application.

For pipe that meets the requirements of this standard, PC denotes the maximum working pressure rating (WPR) for water up to 80°F (27°C),* with the following capacity† for momentary rises in pressure above‡ its maximum working pressure (WP). The following allowable surges are in addition to static pressures:

a. Recurring pressure surges (P_{RS}): The maximum anticipated recurring pressure surges (P_{RS}) do not exceed one-half the pipe's nominal PC (when operating at the maximum working pressure).

b. Occasional pressure surges (P_{OS}): The maximum anticipated occasional pressure surges (P_{OS}) do not exceed the pipe's nominal PC (when operating at the maximum working pressure).

Pressure class (PC) ratings for pipe described in this standard are given in Table 9. The PC values listed in the table identify the maximum working pressure ratings (WPR) of pipe made and classified in accordance with this standard. The PC values assume that the pipe is subject to surges above working pressure that are not in excess of the above-defined surge capacity, and that the pipe operating temperature is limited to a maximum of 80°F (27°C). When higher temperatures are anticipated, the pipe's PC and WPR should be reduced by an appropriate temperature compensating factor (F_T), as indicated in Table 10. The defined surge capacities and corresponding allowable changes in flow velocities are stated in Table B.1 in appendix B. Operation at lower working pressures than the pipe's nominal PC

*When PE pipe and fittings are used to convey liquid with a temperature exceeding 80°F (27°C), the rated pressure class given in Table 9 shall be reduced by an appropriate temperature compensating factor (F_T) as indicated in Table 10. This derating should also be considered where pipelines are exposed to external elevated temperatures.

†The allowance for recurring positive surge pressure included in the pressure class rating is applicable to current PE materials described in this standard. This allowance assumes that the total number of surge events the piping will experience over its intended service life will not exceed one million. Some PE materials provide greater fatigue endurance and permit the use of larger effective allowances. The manufacturer should be consulted for more detailed recommendations.

‡A pipe may sometimes be subjected to net negative internal pressures because of the individual or combined effects of internal negative transients and external forces (such as the water table). When this situation exists, refer to the supplier for information on the hydraulic collapse resistance of the pipeline.

provides for a larger surge pressure capacity in accordance with Sec. 4.6.2 and Sec. B.1 in appendix B.

The HDBs for PE materials described in this standard are identified in Table 9. These HDBs, which have been established from long-term pressure testing using water at 73.4°F (23°C), are applicable for service temperatures up to 80°F (27°C).

Table 9 Pressure class/maximum working pressure rating (see note)

Material	PE 3408		PE 3406 and PE 2406	
Hydrostatic Design Basis (HDB) for 73.4°F (23°C)	1,600 <i>psi</i> (11.03 <i>MPa</i>)		1,250 <i>psi</i> (8.62 <i>MPa</i>)	
Hydrostatic Design Stress (HDS)	800 <i>psi</i> (5.52 <i>MPa</i>)		625 <i>psi</i> (4.31 <i>MPa</i>)	
Dimension Ratio	<i>psig</i>	<i>(kPa)</i>	<i>psig</i>	<i>(kPa)</i>
32.5	51	(352)	40	(276)
26.0	64	(441)	50	(345)
21.0	80	(551)	63	(434)
17.0	100	(689)	78	(538)
15.5	110	(758)	86	(593)
13.5	128	(883)	100	(689)
11.0	160	(1,103)	125	(862)
9.3	193	(1,331)	151	(1,041)
9.0	200	(1,379)	156	(1,076)
7.3	254	(1,751)	198	(1,365)

NOTE: The pressure class (PC) and working pressure rating (WPR) are equal through the range of surge pressures and velocity changes listed in Table B.1 of appendix B. Values are applicable through 80°F (27°C).

Table 10 Temperature compensation multipliers (F_T)

Maximum Operating Temperature		Multiplier (F_T)
°F	°C	
up to 80	up to 27	1.0
from 81 to 90	from 28 to 32	0.9
from 91 to 100	from 33 to 38	0.8
above 100	above 38	*

*The upper operating temperature limit, as well as the temperature compensation multiplier for temperatures above 100°F (38°C), can vary depending on the pipe material. The pipe manufacturer should be consulted for this information.

4.6.2 *Working pressure rating (WPR)*. The working pressure rating establishes a pipe's pressure design capacity for the anticipated system temperature and surge pressure conditions. It is determined from the PC using Eq 2, 3, and 4. The WPR of a pipe is the lesser of the following values, where F_T is the temperature compensating factor for cases where the operating temperature exceeds 80°F (27°C) as indicated in Table 10.

- a. The pipe's nominal PC adjusted for temperature, when above 80°F (27°C):

$$WPR = (PC) F_T \quad (\text{Eq 2})$$

or

- b. One and a half times the pipe's nominal PC less the maximum pressure resulting from recurring surge pressure:

$$WPR = [1.5 (PC) F_T] - P_{RS} \quad (\text{Eq 3})$$

or

- c. Two times the pipe's nominal PC less the maximum pressure resulting from occasional surge pressure:

$$WPR = [2 (PC) F_T] - P_{OS} \quad (\text{Eq 4})$$

In summary, the WPR (which considers pipe DR system surges and temperature) must be equal to or greater than the WP of the system with consideration for the effect of anticipated surge pressure.

$$\text{WPR} \geq \text{WP} \quad (\text{Eq 5})$$

The surge pressure (P_s) that is caused by a sudden change in water velocity may be computed using accepted surge pressure equations. An example of the procedure used to determine the WPR for a pipe in a certain set of assumed operating conditions is provided in appendix C.2.

Estimated surge pressures for PE pipe for a given sudden change in water flow velocity are listed in C.1 in the appendix to this standard.

SECTION 5: VERIFICATION

Sec. 5.1 General

The manufacturer shall take sufficient measures to check incoming materials and to produce pipe that complies with the requirements of this standard. The following tests relative to qualification of compounds and manufacturing processes and for quality assurance shall be conducted at or more often than the indicated intervals, unless otherwise specified by the purchaser. The actual frequency at which each of these tests is conducted should be determined in the manufacturer's quality-control program, which shall be designed to ensure compliance with the requirements of this standard.

Sec. 5.2 Material Testing Requirements

5.2.1 Incoming material. Incoming lots of PE materials shall be sampled and tested for melt-flow index and density by the manufacturer. The manufacturer or the resin supplier shall test each lot of material for thermal stability. The test results shall be within the limits established by the supplier or manufacturer.

5.2.2 Rework material. Rework materials shall meet the requirements of Sec. 4.2.4 of this standard.

Sec. 5.3 Manufacturer Qualification

For each lot of PE material, one size of pipe manufactured in each size range—4 to 12 in. (100 to 300 mm), greater than 12 to less than 24 in. (300 to less than 600 mm), and 24 in. (600 mm) and larger—shall be tested in accordance with Sec. 5.3.1 and Sec. 5.3.2 and meet the standards in Sec. 4.2.7 and Sec. 4.3.4. For each material, one pipe size from each size range shall be tested at the beginning of production and semiannually thereafter.

5.3.1 *Elevated temperature sustained pressure.* The tested pipe shall comply with the requirements given in Sec. 4.2.6.

5.3.2 *Thermal stability.* A test specimen taken from the midwall of the pipe shall comply with the requirement given in Sec. 4.3.4.

Sec. 5.4 Pipe Testing Requirements

5.4.1 *Workmanship.* Each length of pipe surface shall be visually checked inside and out for defects as described in Sec. 4.3.1, and the presence of these defects shall be cause to reject the pipe.

5.4.2 *Dimensions and tolerances.* Dimensions and tolerances shall be measured once per hour or once per length of pipe, whichever is less frequent.

5.4.3 *Bend-back test.* This test shall be performed daily or at least once per production run, whichever is more frequent, on specimens prepared as described in Sec. 5.7. A sufficient number of specimens shall be tested to ensure that representative samples of the entire inside surface of the pipe have been tested. The elongation-at-break test (Sec. 4.3.8) may be substituted for this test.

5.4.4 *Elongation-at-break test.* This test shall be performed daily or at least once per production run, whichever is more frequent. The bend-back test (Sec. 4.3.7) may be substituted for this test.

5.4.5 *Ring-tensile strength test.* This test shall be performed at least once per production run. The quick-burst test (Sec. 4.3.6) or the five-second pressure test (Sec. 4.3.9) may be substituted for this test.

5.4.6 *Quick-burst test.* This test shall be performed at least once per production run. The ring-tensile strength test (Sec. 4.3.5) or the five-second pressure test (Sec. 4.3.9) may be substituted for this test.

5.4.7 *Carbon-black content.* Carbon-black levels shall be determined daily or for each production run of pipe, whichever is more frequent.

5.4.8 *Five-second pressure test.* This test shall be performed at least once per production run. The ring-tensile strength test (Sec. 4.3.5) or the quick-burst test (Sec. 4.3.6) may be substituted for this test.

5.4.9 *Melt-flow index.* This test shall be run on samples from the pipe at least once per day.

5.4.10 *Density.* This test shall be run on samples from the pipe once per day or once per lot of precompounded black PE material, whichever is more frequent.

5.4.11 *Marking.* Each length of pipe shall be visually examined and checked for marking accuracy and legibility.

Sec. 5.5 Fitting Testing Requirements

5.5.1 *Workmanship.* Each fitting shall be visually checked inside and outside for defects as described in Sec. 4.3.1, and the presence of these defects shall be cause to reject the fitting.

5.5.2 *Five-second pressure test.* This test shall be performed on the first fitting of a particular outside diameter and style, and every fiftieth fitting thereafter, for fabricated fittings only. Fittings that are produced by injection molding shall be tested once per production run.

Fitting styles are characterized as elbows, tees, reducing tees, reducing laterals, branch saddles, flange adapters, mechanical joint adapters, and end caps. The five-second pressure test shall be as referenced in Sec. 4.3.9. The elevated temperature sustained pressure test detailed in Sec. 4.2.6 may be substituted for this test.

Sec. 5.6 Provision for Test Sample Failure

When any PE product fails to meet a requirement of this or a referenced standard, additional tests shall be performed to determine which products are acceptable of those produced from the same extruder or mold since the last favorable test. Products failing to meet any of these requirements shall be rejected.

Sec. 5.7 Bend-Back Test

5.7.1 *Definitions.*

5.7.1.1 *Cracking.* A split or separation of material that is exhibited as a surface discontinuity.

5.7.1.2 *Crazing.* Apparent fine cracks at or under the surface, which may be exhibited by visible fine white lines.

5.7.2 *Apparatus.*

5.7.2.1 *Equipment.* Any suitable equipment such as band saw, jigsaw, or router is useful for specimen preparation.

5.7.2.2 *Vise.* A vise with a minimum of 2 in. × 2 in. (51 mm × 51 mm) flat parallel plates that are capable of at least 3 in. (76 mm) of travel or other suitable bending equipment is required to perform the test procedure.

5.7.3 *Specimen preparation.* A ring of pipe with a minimum width of 1¼ in. (32 mm) should be squarely cut from the pipe.

When the ring has a wall thickness greater than 3/8 in. (9.5 mm), material may be removed from the outside surface, while maintaining an undisturbed inside surface, to produce a ring with a 3/8 in. (9.5 mm) wall thickness. This will facilitate performing the bend-back test.

NOTE: In order to facilitate this procedure, the ring obtained in paragraph 5.7.5.2 may be tested in its entirety or may be cut into representative sectors to produce bend-back test specimens. It is important that several specimens be tested to ensure that representative samples of the inside surface are tested.

5.7.4 *Conditioning.*

5.7.4.1 *Temperature.* The test shall be performed at 73.4°F ± 3.6°F (23°C ± 2°) unless otherwise specified. Test specimens shall be conditioned to the proper temperature before testing.

5.7.4.2 *Conditioning.* In cases of disagreement, specimens shall be conditioned according to procedure A of ASTM D618.

5.7.5 *Test procedure.* The following procedure shall be followed for each test specimen procured. The complete procedure shall be performed in a period not exceeding 5 min.

5.7.5.1 The specimen is bent by hand and placed in the vise or apparatus so that, when the vise is closed, the specimen shall protrude above the top of the vise or apparatus sufficiently to allow the strained area to be examined.

5.7.5.2 The vise is gradually closed until the surfaces or the outside wall of the pipe come into contact.

5.7.5.3 The bent inside surface of the pipe shall be examined in a well-lit area for signs of cracking or crazing.

5.7.6 *Cracking or crazing.* Any indication of cracking or crazing is cause for rejection of the pipe.

Sec. 5.8 Plant Inspection by Purchaser

5.8.1 *Production notice.* When plant inspection is required by the purchaser, the manufacturer shall provide the purchaser with adequate advance notice of when and where production of ordered materials will begin.

5.8.2 *Manufacturer's responsibility.* Plant inspection by the purchaser or the omission of these inspections shall not relieve the manufacturer of the responsibility to provide materials complying with the applicable requirements of this standard and of the purchaser.

5.8.3 *Plant access.* The purchaser shall have free access to those parts of the manufacturer's plant that are necessary to ensure that products comply with requirements.

5.8.4 *Inspection aids.* The manufacturer shall make available for use by the purchaser, without charge, the tools and assistance that are necessary for the inspection and handling of materials.

SECTION 6: DELIVERY

Sec. 6.1 Marking

6.1.1 *General.*

6.1.1.1 Marking the product with the designation "ANSI/AWWA C906" affirms that the product has been manufactured, inspected, sampled, and tested in accordance with this standard and has been found to meet its requirements.

6.1.1.2 Pipe shall bear identification markings that will remain legible during normal handling and storage. The markings shall be applied in a manner that will not reduce the strength or otherwise damage the pipe.

6.1.2 *Required markings.* Minimum marking on the pipe shall include the following and shall be applied so that intervals between markings are no greater than 5 ft (1.5 m):

- a. Nominal size and OD base (such as 18 in. IPS, 12 in. DIOD, or 400 mm ISO).
- b. Standard material code designation (such as PE 3408).
- c. Dimension ratio (such as DR 17).
- d. Pressure class (such as PC 100).
- e. AWWA designation number for this standard, ANSI/AWWA C906.

f. Manufacturer's production code to include day, month, year, and the additional markings that may be agreed on by the manufacturer and purchaser, as long as they do not interfere with the legibility of the required markings.

Exceptions to these requirements may only be made with the mutual consent of the manufacturer and the purchaser.

6.1.3 *Marking for special sizes.* For special sizes of pipe (Sec. 4.3.3), the required markings shall be as determined by the mutual consent of the purchaser and the manufacturer.

Sec. 6.2 Shipping

Pipe and fittings, unless otherwise specified by the purchaser, shall be prepared for standard commercial shipment. Care shall be taken during shipment to prevent cuts, scratches, and other damage.

Sec. 6.3 Affidavit of Compliance

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

APPENDIX A

Bibliography

This appendix is for information only and is not a part of ANSI/AWWA C906.

SECTION A.1: GENERAL REFERENCES

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APPENDIX B

Pipe Classification and Working Pressure Rating

This appendix is for information only and is not a part of ANSI/AWWA C906.

SECTION B.1: PRESSURE SURGE CAPACITY

The surge capacities and maximum corresponding velocity changes stated in Table B.1 apply to pipe operating at its nominal pressure class and at temperatures below 80°F (27°C).

Table B.1 Allowable maximum surge pressure surges above working pressure (WP) and corresponding estimated maximum allowable sudden change in water velocity for pipe operating at 80°F (27°C) and at a maximum working pressure (WP) equal to the pipe's nominal pressure class (PC)*

SDR	PE 3408 Materials				PE 3406 & PE 2406 Materials			
	Recurring Surge Events [†]		Occasional Surge Events [†]		Recurring Surge Events [†]		Occasional Surge Events [†]	
	Surge Capacity	Corres. Sudden Velocity Change	Surge Capacity	Corres. Sudden Velocity Change	Surge Capacity	Corres. Sudden Velocity Change	Surge Capacity	Corres. Sudden Velocity Change
	(psi)	(fps)	(psi)	(fps)	(psi)	(fps)	(psi)	(fps)
7.3	127.0	6.9	254.0	13.8	99.2	5.4	198.4	10.8
9.0	100.0	6.2	200.0	12.4	78.1	4.8	156.3	9.7
9.3	96.4	6.1	192.8	12.2	75.3	4.7	150.6	9.5
11.0	80.0	5.6	160.0	11.1	62.5	4.3	125.0	8.7
13.5	64.0	5.0	128.0	10.0	50.0	3.9	100.0	7.8
15.5	55.2	4.7	110.3	9.3	43.1	3.6	86.2	7.3
17.0	50.0	4.4	100.0	8.9	39.1	3.5	78.1	6.9
21.0	40.0	4.0	80.0	8.0	31.3	3.1	62.5	6.2
26.0	32.0	3.6	64.0	7.2	25.0	2.8	50.0	5.6
32.5	25.4	3.2	50.8	6.4	19.8	2.5	39.7	5.0

*The surge pressure tolerances stated in this table apply only to pipe and not to system components, which may have lesser tolerances. The design should consider possible system reactions and their potential effect on system components. Should higher sudden velocity changes and surge pressures be anticipated than allowable in accordance with this table, the pipe's working pressure rating (WPR) will have to be reduced. See Sec. 4.6.2.

†See Sec. 3 for definition of recurring and occasional surge pressure. The estimated maximum sudden change in water velocity that corresponds to a given pressure surge has been calculated in accordance with the procedure stated in AWWA Committee Report on Design and Installation of Polyethylene Pipe Made in Accordance with ANSI/AWWA C906.

NOTE: A pipe may sometimes be subjected to net negative internal pressure because of the individual or combined effect of internal negative transients and external forces (such as the water table). When this situation exists, refer to the supplier for information on the hydraulic collapse resistance of the pipeline.

For pipe that is operating at a condition where its working pressure is below the pipe's nominal PC, its surge pressure capacity is generally greater in accordance with the following [where F_T is the temperature compensating factor for cases where the operating temperature exceeds 80°F (27°C)*]:

a. The sum of the maximum anticipated working pressure (WP) and the maximum anticipated recurring pressure surge (P_{RS}) may be no greater than 1.5 times the pipe's nominal PC; and

$$WP + P_{RS} \leq 1.5 PC \times F_T \quad (\text{Eq B-1})$$

b. The sum of the maximum anticipated working pressure (WP) and the maximum anticipated occasional pressure surge (P_{OS}) may be no greater than two times the pipe's nominal size PC; and

$$WP + P_{OS} \leq 2.0 PC \times F_T \quad (\text{Eq B-2})$$

c. In all cases,

$$WP \leq PC \times F_T \quad (\text{Eq B-3})$$

*The pressure capacity of PE pipe and fittings that operate at temperatures above 80°F (27°C) shall be reduced by an appropriate temperature reduction factor (F_T).

APPENDIX C

Working Pressure Rating and Pressure Class

This appendix is for information only and is not a part of ANSI/AWWA C906.

Sec. C.1 Working Pressure Rating and Pressure-Class Selection—Examples

Example C.1.1: A water utility wishes to use high-density PE 3408 pipe in a buried water main service subject to a maximum summer water temperature of 80°F (27°C), a maximum sustained working pressure of 90 psig, recurring surge pressures caused by sudden changes in flow velocity not exceeding 3 fps, and occasional surges caused by changes in flow velocity not exceeding 6 fps. Because of its apparent nominal working pressure capacity, the preliminary design choice for this application is pipe of DR 17 designated as PC 100 with a maximum working pressure rating of 100 psig.

Given: WP = 90 psig

ΔV = 3 fps recurring velocity change

ΔV = 6 fps occasional velocity change

DR 17 HDPE PE 3408 pipe (maximum WPR 100 psig; PC 100)

Calculate: P_{RS} , P_{OS} , and WPR per Sec. 4.6.3.

Using the conventional surge pressure formula applicable to metal and plastic pipe, the values calculated are: P_{RS} = 33.9 psig surge; P_{OS} = 67.8 psig surge (see Table C.1).

Table C.1 Surge pressure per foot of extinguished velocity by pipe DR for PE 3408 materials

Pressure Surge at 1.0 fps, psig (kPa)		
SDR	1 fps	0.3 mps
7.3	18.4 psi	126.8 kPa
9.0	16.2 psi	111.5 kPa
9.3	15.9 psi	109.4 kPa
11.0	14.4 psi	99.1 kPa
13.5	12.8 psi	88.2 kPa
15.5	11.8 psi	81.6 kPa
17.0	11.3 psi	77.6 kPa
21.0	10.0 psi	69.2 kPa
26.0	8.9 psi	61.7 kPa
32.5	8.0 psi	54.9 kPa

Examination of Table B.1 in appendix B shows that the expected surges are within the surge capacity of the DR 17 pipe for both recurring and occasional surge events. DR 17 should be acceptable.

Alternately, this is confirmed by calculating WPR per Sec. 4.6.3 as the lesser of the following:

$$\text{WPR} = 100 \text{ psig} \quad (\text{Eq C-1})$$

or

$$\begin{aligned} \text{WPR} &= 1.5 \times 100 \text{ psig} - 33.8 \text{ psig} = 116.2 \text{ psig} \\ &(\text{recurring surge condition}) \end{aligned} \quad (\text{Eq C-2})$$

or

$$\begin{aligned} \text{WPR} &= 2.0 \times 100 \text{ psig} - 67.8 \text{ psig} = 132.2 \text{ psig} \\ &(\text{occasional surge condition}) \end{aligned} \quad (\text{Eq C-3})$$

Therefore, WPR = 100 psig.

Check: $\text{WPR} \geq \text{WP}$; $100 \text{ psig} \geq 90 \text{ psig}$; DR 17 is acceptable.

Specification: DR 17 pipe with maximum working pressure rating of 100 psig, also designated as PC 100.

Example C.1.2: A water utility is considering PC 80 (DR 21) PE 3408 pipe for buried water main service for which the sustained working pressure will be 75 psi, and the maximum water service temperature is lower than 80°F (27°C). However, the designer expects the pipe to endure the particular operating conditions in which the recurring surge and occasional surge pressures both result from a sudden velocity change of up to 5 feet per second.

Given: $\text{WP} = 75 \text{ psig}$

$\Delta V = 5 \text{ fps}$ recurring and occasional velocity change

DR 21 PE 3408 pipe (maximum WPR 80 psig; PC 80).

Calculations: P_{RS} , P_{OS} , and WPR per Sec. 4.6.3 (refer also to Tables C.1 and C.2).

Using the conventional surge pressure formulas applicable to metal and plastic pipe, the value for the surge pressure rise per foot of extinguished velocity in DR 21 pipe is 10 psig per fps velocity change. Therefore, $P_{RS} = P_{OS} = 5 \times 10 \text{ psig} = 50 \text{ psig}$ surge.

Table C.2 Working pressure rating by DR for velocity changes for PE 3408 materials*

SDR	Working Pressure Rating (based on recurring surge)												
	Velocity (fps)												
	0	1	2	3	4	4.5	5	5.5	6	7	8	9	10
7.3	254	254	254	254	254	254	254	254	254	252	234	215	197
9.0	200	200	200	200	200	200	200	200	200	187	171	154	138
9.3	193	193	193	193	193	193	193	193	193	178	162	146	132
11.0	160	160	160	160	160	160	160		154	139	125	111	96
13.5	128	128	128	128	128	128	128		115	102	90	77	64
15.5	110	110	110	110	110		106		94	83	71	59	47
17.0	100	100	100	100	100		94		82	71	60	49	37
21.0	80	80	80	80	80		70		60	50	40	30	20
26.0	64	64	64	64	60		51		42	33	24	15	7
32.5	51	51	51	51	44		36		28	20	13	5	0

*NOTE: The shaded area indicates where the WPR and PC are identical.

Evaluate WPR as described in Sec. 4.6.3 as the lesser of the following:

$$\text{WPR} = 80 \text{ psig} \quad (\text{Eq C-4})$$

or

$$\begin{aligned} \text{WPR} &= 1.5 \times 80 \text{ psig} - 50 \text{ psig} = 70 \text{ psig} \\ &(\text{recurring surge condition}) \end{aligned} \quad (\text{Eq C-5})$$

or

$$\begin{aligned} \text{WPR} &= 2.0 \times 80 \text{ psig} - 50 \text{ psig} = 110 \text{ psig} \\ &(\text{occasional surge condition}) \end{aligned} \quad (\text{Eq C-6})$$

Therefore, WPR = 70 psig.

Check: $\text{WPR} \geq \text{WP}$; $70 \text{ psig} \leq 75 \text{ psig}$; DR 21 is not acceptable to operate at 75 psig working pressure and 5 fps surge conditions. Its surge capacity per Table B.1 in appendix B is exceeded. DR 21 may be used only if the designer can operate the water main at working pressure less than 70 psig, or if the surge at 5 fps was attributed to occasional events only with recurring surges at 4 fps or less (refer to Table C.2).

Otherwise, examination of DR 17 with its surge capacity of 50 psig per Table B.1 in appendix B should prove acceptable at 75 psig working pressure. For DR 17, $P_{RS} = P_{OS} = 56.5 \text{ psig}$ for 5 fps extinguished velocity. The WPR is calculated as the lesser of

$$\text{WPR} = 100 \text{ psig} \quad (\text{Eq C-7})$$

or

$$\text{WPR} = 1.5 \times 100 \text{ psi} - 56.5 = 93.5 \text{ psig} \quad (\text{Eq C-8})$$

or

$$\text{WPR} = 2.0 \times 100 \text{ psi} - 56.5 = 143.5 \text{ psig} \quad (\text{Eq C-9})$$

Therefore, WPR = 93.5 psig.

Check: $\text{WPR} \geq \text{WP}$; $93.5 \text{ psig} \geq 75 \text{ psig}$; DR 17 is acceptable.

Specification: DR 17 with a maximum working pressure rating of 100 psig, also designated as PC 100.

NOTE: Although the DR 17 surge capacity value was exceeded, the sustained pressure capacity was underutilized. The resultant net peak stress during the surge event remains less than the peak stress capability of the pipe; therefore, long-term performance is assured. This is also confirmed in Table C.2, Working Pressure Rating by DR for Velocity Changes.

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