



Standard Specification for Polyethylene (PE) Plastic Pipe, Schedule 40¹

This standard is issued under the fixed designation D2104; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers polyethylene (PE) pipe made in Schedule 40 size for use with insert fittings (inside diameter controlled) and pressure-rated for water (see Appendix). Included are criteria for classifying PE plastic pipe materials and PE plastic pipe, a system of nomenclature for PE plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, and environmental stress cracking. Requirements for marking are also given.

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

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 7, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- D618 Practice for Conditioning Plastics for Testing
- D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
- D1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
- D1505 Test Method for Density of Plastics by the Density-Gradient Technique
- D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
- D1599 Test Method for Resistance to Short-Time Hydraulic

- Pressure of Plastic Pipe, Tubing, and Fittings
- D1600 Terminology for Abbreviated Terms Relating to Plastics
- D1603 Test Method for Carbon Black Content in Olefin Plastics
- D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
- D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
- D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
- F412 Terminology Relating to Plastic Piping Systems
- 2.2 NSF Standard:
Standard No. 14 Plastic Piping Components and Related Materials³
Standard No. 61 for Drinking Water Systems Components—Health Effects³

3. Terminology

3.1 *Definitions*—are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for polyethylene plastic is PE.

3.1.1 *hydrostatic design stress*—the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic water pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.

3.1.2 *pressure rating (PR)*—the estimated maximum pressure that water in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

3.1.3 *relation between dimensions, hydrostatic design stress, and pressure rating*—the following expression, commonly known as the ISO equation,⁴ is used in this specification to relate dimensions, hydrostatic design stress, and pressure rating:

$$2S/P = (D_i/t) + 1 \quad (1)$$

¹ This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.26 on Olefin Based Pipe.

Current edition approved Aug. 10, 2003. Published September 2003. Originally approved in 1962. Last previous edition approved in 2001 as D2104 – 01. DOI: 10.1520/D2104-03.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

⁴ ISO R 161-1960, Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part 1, Metric Series.

where:

- S = hydrostatic design stress, psi (or MPa) (or bar),
 P = pressure rating, psi (or MPa) (or bar),
 D_i = average inside diameter, in. (or mm), and
 t = minimum wall thickness, in. (or mm).

3.1.4 *standard thermoplastic pipe materials designation code*—the pipe materials designation code shall consist of the abbreviation PE for the type of plastic, followed by the ASTM grade in Arabic numerals and the hydrostatic design stress in units of 100 psi with any decimal figures dropped. Where the hydrostatic design stress code contains less than two figures, a cipher shall be used before the number. Thus a complete material code shall consist of two letters and four figures for PE plastic pipe materials (see Section 5).

4. Pipe Classification

4.1 *General*—This specification covers PE pipe made from five PE plastic pipe materials in Schedule 40 size with inside diameter controlled.

5. Materials

5.1 *General*—Polyethylene plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria, namely, (1) short-term strength tests, and (2) long-term strength tests.

NOTE 1—The PE pipe intended for use in the transport of potable water is capable of being evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation shall be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in NSF Standard No. 14. The seal or mark of the laboratory making the evaluation shall be included on the pipe.

5.2 *Basic Materials*—This specification covers PE pipe made from four PE plastics as defined in Specification D1248, in which the requirements are based on short-term tests. These are Grade P 14, Grade P 23, Grade P 24, Grade P 33, and Grade P 34. The PE plastics are capable of being described according to the appropriate cell classification in accordance with Specification D3350. The 80°C sustained pressure performance requirements of 6.8.3 (pipe test category in Table 5) are not currently in PE material Specifications D1248 or D3350. To identify the correct pipe test category (C1 to C7), the PE material base resin density and melt index must be obtained from the PE material supplier.

NOTE 2—Committee F-17 has requested that Committee D-20 add the 80°C sustained pressure performance requirements to Specifications D1248 and D3350.

5.3 *Hydrostatic Design Stresses*—This specification covers PE pipe made from three PE plastics as defined by hydrostatic design stresses developed on the basis of long-term tests (appendix).

5.4 *Compound*—The PE plastic extrusion compound shall meet the requirements of either Grade P 14, Class C; Grade P 23, Class C; Grade P 24, Class C; Grade P 33, Class C; or Grade P 34, Class C material as described in Specification D1248, or the comparable cell classification in accordance with Specification D3350.

5.5 *Rework Material*—Clean, rework material, generated from the manufacturer’s own pipe production, is capable of

being used by the same manufacturer, as long as the pipe produced meets all the requirements of this specification.

6. Requirements

6.1 *Workmanship*—The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.2 *Dimensions and Tolerances*—All dimensions shall be measured in accordance with Test Method D2122 using an acceptable length of pipe.

6.2.1 *Inside Diameters*—Classify the pipe as roundable or nonroundable as defined in Test Method D2122, and determine the inside diameter of the pipe accordingly. The inside diameters and tolerances shall be as shown in Table 1.

NOTE 3—Six-inch, inside diameter controlled Schedule 40 pipe meets the dimensional requirements of roundable pipe, and most polyethylenes used to make inside diameter controlled Schedule 40 pipe meet the tensile requirements for roundable pipe.

6.2.2 *Wall Thicknesses*—The wall thicknesses and tolerances shall be as shown in Table 2 when measured at both ends of the pipe to the nearest 0.001 in. (0.02 mm), in accordance with Test Method D2122.

6.2.3 *Eccentricity*—The eccentricity or wall thickness ranges, E , of the inside and outside circumferences of the pipe shall be within 12 %.

6.2.4 *Thickness of Outer Layer*—For pipe produced by simultaneous multiple extrusion, that is, pipe containing two or more concentric layers, the outer layer shall be at least 0.020 in. (0.52 mm) thick.

6.3 *Bond*—For pipe produced by simultaneous multiple extrusion, the bond between the layers shall be strong and uniform. It shall not be possible to separate any two layers with a probe or point of a knife blade so that the layers separate cleanly at any point.

6.4 *Carbon Black*—The polyethylene pipe extrusion compound shall contain at least 2 % carbon black when tested in

TABLE 1 Inside Diameters and Tolerances for PE Plastic Pipe, Schedule 40, in.(mm)

Nominal Pipe Size	Average Inside Diameter	Tolerances
1/2	0.622(15.80)	+0.010(+0.25) −0.010(−0.25)
3/4	0.824(20.93)	+0.010(+0.25) −0.015(−0.38)
1	1.049(26.64)	+0.010(+0.25) −0.020(−0.51)
1 1/4	1.380(35.05)	+0.010(+0.25) −0.020(−0.51)
1 1/2	1.610(40.89)	+0.015(+0.38) −0.020(−0.51)
2	2.067(52.50)	+0.015(+0.38) −0.020(−0.51)
2 1/2	2.469(62.71)	+0.015(+0.38) −0.025(−0.64)
3	3.068(77.93)	+0.015(+0.38) −0.030(−0.76)
4	4.026(102.26)	+0.015(+0.38) −0.035(−0.89)
6	6.065(154.05)	+0.020(+0.51) −0.035(−0.89)

TABLE 2 Wall Thicknesses and Tolerances for PE Plastic Pipe, Schedule 40, in.(mm)

Nominal Pipe Size	Wall Thickness ^A	
	Minimum	Tolerance ^B
1/2	0.109(2.77)	+0.020(+0.51)
3/4	0.113(2.87)	+0.020(+0.51)
1	0.133(3.38)	+0.020(+0.51)
1	0.140(3.56)	+0.020(+0.51)
1 1/2	0.145(3.68)	+0.020(+0.51)
2	0.154(3.91)	+0.020(+0.51)
2 1/2	0.203(5.16)	+0.024(+0.61)
3	0.216(5.49)	+0.026(+0.66)
4	0.237(6.02)	+0.028(+0.71)
6	0.280(7.11)	+0.034(+0.86)

^AThe minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

^BThis is limited by the eccentricity requirements, see 6.2.3.

accordance with Test Method D1603. For pipe produced by simultaneous multiple extrusion, this requirement shall apply to the outer layer.

NOTE 4—There is evidence that type, particle size, and dispersion quality of the carbon black affects the weatherability of the pipe. The problem is being investigated and when reliable test methods are developed, requirements for weatherability, or other suitable requirements to cover this property, will be included in a revision of this specification.

6.5 Density—The polyethylene base resin (uncolored PE) in the pipe compound shall have a density in the range from 0.910 to 0.925 g/cm³ for pipe made from Grade P 14 of Specification D1248, 0.926 to 0.940 g/cm³ for pipe made from Grade P 23 and Grade P 24 of Specification D1248, 0.941 to 0.965 g/cm³ for pipe made from Grade P 33 of Specification D1248, and 0.941 to 0.965 g/cm³ for pipe made from Grade P 34 of Specification D1248, when determined in accordance with 7.4.

6.6 Burst Pressure—The minimum burst pressure for PE plastic pipe shall be as given in Table 3 and Table 4, when determined in accordance with 7.8.

TABLE 3 Burst Pressure Requirements for Water at 23°C (73.4°F) for PE Plastic Pipe, Schedule 40, (MPa (bar))

Nominal Pipe Size, in.	Min Burst Pressure, MPa (bar) ^A			
	PE2306 PE2406 PE3306 PE3406	PE2305	PE1404	
1/2	5.17(51.7)	4.14(41.4)	2.55(25.5)	
3/4	4.21(42.1)	3.31(33.1)	2.07(20.7)	
1	3.93(39.3)	3.10(31.0)	1.93(19.3)	
1 1/4	3.17(31.7)	2.55(25.5)	1.59(15.9)	
1 1/2	2.90(29.0)	2.28(22.8)	1.45(14.5)	
2	2.41(24.1)	1.93(19.3)	1.17(11.7)	
2 1/2	2.62(26.2)	2.07(20.7)	1.31(13.1)	
3	2.28(22.8)	1.79(17.9)	1.10(11.0)	
4	1.93(19.3)	1.52(15.2)	0.97(9.7)	
6	1.52(15.2)	1.24(12.4)	0.76(7.6)	

^AThe fiber stresses used to derive these test pressures are as follows:

At 23°C (73.4°F):	
PE2306, PE2406, PE3306, and PE3406	17.37(173.7)
PE2305	13.79(137.9)
PE1404	8.62(86.2)

TABLE 4 Burst Pressure Requirements for Water at 23°C (73.4°F) for PE Plastic Pipe, Schedule 40, (psi)

Nominal Pipe Size, in.	Min Burst Pressure, psi ^A			
	PE2306 PE2406 PE3306 PE3406	PE2305	PE1404	
1/2	750	600	370	
3/4	610	480	300	
1	570	450	280	
1 1/4	460	370	230	
1 1/2	420	330	210	
2	350	280	170	
2 1/2	380	300	190	
3	330	260	160	
4	280	220	140	
6	220	180	110	

^AThe fiber stresses used to derive these test pressures are as follows:

At 23°C (73.4°F):	
PE2306, PE2406, PE3306, and PE3406	2520 psi
PE2305	2000 psi
PE1404	1250 psi

6.7 Environmental Stress Cracking—There shall be no loss of pressure in the pipe when tested in accordance with 7.7.

6.8 Sustained Pressure—Pipe made from PE materials designated PE2406, PE3406 or PE3408 shall meet the requirement of 6.8.1. Pipe made from other PE materials shall meet the requirements of 6.8.2 and 6.8.3.

6.8.1 The average failure time and failure time of two of the three specimens shall meet or exceed the minimum values shown in Table 5 when tested in accordance with 7.7.1.

6.8.2 Sustained Pressure—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598, at the test pressures given in Table 6 and Table 7, when tested in accordance with 7.5.

6.8.3 Elevated Temperature Sustained Pressure—The average failure time must meet or exceed the specified minimum average failure time in Table 8 for both hoop stresses of a given pipe test category when tested in accordance with 7.7.

7. Test Methods

7.1 Conditioning—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618 for those tests where conditioning is required.

7.2 Test Conditions—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

7.3 Sampling—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

TABLE 5 Minimum Average Time to Failure (h) versus Test Hoop Stress

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