



# Standard Specification for Polyethylene (PE) Thermoplastic High-Pressure Irrigation Pipeline Systems<sup>1</sup>

This standard is issued under the fixed designation F 771; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>e1</sup> NOTE—Keywords added editorially in November 2003.

## 1. Scope

1.1 This specification covers polyethylene (PE) thermoplastic pipelines used to convey, at rated pressures of 80 to 200 psi, water that is to be used for irrigation purposes. This specification includes criteria for classifying the pipe materials, a system of nomenclature for plastic pipe, requirements for pipe, test methods, joints, fittings, certification, and marking.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 The following safety hazards caveat pertains only to the test method 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:

- D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastomer<sup>2</sup>
- D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable<sup>3</sup>
- D 1505 Test Method for Density of Plastics by the Density-Gradient Technique<sup>2</sup>
- D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure<sup>4</sup>
- D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings<sup>4</sup>
- D 1600 Terminology for Abbreviated Terms Relating to Plastic<sup>2</sup>
- D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings<sup>4</sup>

D 2239 Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Control Inside Diameter<sup>4</sup>

D 2609 Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe<sup>4</sup>

D 2683 Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing<sup>4</sup>

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials<sup>4</sup>

D 3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter<sup>4</sup>

D 3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing<sup>4</sup>

D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials<sup>5</sup>

F 412 Terminology Relating to Plastic Piping Systems<sup>4</sup>

### 2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>6</sup>

### 2.3 Military Standard:

MIL-STD-129 Marking for Shipment and Storage<sup>6</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *General*—Nomenclature is in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.1.2 *high-pressure irrigation pipeline*—this term applies to underground pipelines constructed of PE pipe from 0.5 to 6 in. nominal diameter and subject to pressures, including surge pressures, from 80 to 200 psi (550 to 1380 kPa).

3.1.3 *hydrostatic design stress*—the recommended maximum hoop stress that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.

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

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<sup>2</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>3</sup> Annual Book of ASTM Standards, Vol 08.03.

<sup>4</sup> Annual Book of ASTM Standards, Vol 08.04.

<sup>5</sup> Annual Book of ASTM Standards, Vol 08.03.

<sup>6</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.1.5 *relation between standard dimension ratio, hydrostatic design stress and pressure rating*—the following expression, commonly known as the ISO equation, is used to relate standard dimension ratio, hydrostatic design stress, and pressure rating:

For outside diameter-controlled pipe:

$$2S/P = \text{SDR} - 1 \text{ or } 2S/P = (D_o/t) - 1 \quad (1)$$

For inside diameter-controlled pipe:

$$2S/P = \text{SIDR} + 1 \text{ or } 2S/P = (D_i/t) + 1 \quad (2)$$

where:

- S = hydrostatic design stress, psi (or kPa),
- P = pressure rating, psi (or kPa),
- $D_o$  = average outside diameter, in. (or mm),
- $D_i$  = average inside diameter, in. (or mm),
- SDR =  $D_o/t$ , and
- SIDR =  $D_i/t$ .

3.1.6 *standard dimension ratios (SDR)*—a specific ratio of the average specified outside diameter to the minimum specified wall thickness

$$D_o/t \quad (3)$$

for outside diameter-controlled plastic pipe, the value of which is derived by adding one to the pertinent number selected from the ANSI preferred number series 10.

3.1.7 *standard inside diameter dimension ratio (SIDR)*—a specific ratio of the average specified inside diameter to the minimum specified wall thickness

$$D_i/t \quad (4)$$

for inside diameter-controlled plastic pipe, the value of which is derived by subtracting one from the pertinent number selected from the ANSI preferred number series 10.

3.1.8 *standard thermoplastic pipe material designation code*—the pipe material designation code consists of the abbreviation PE, followed by the Specification D 1248 grade in arabic numerals and the hydrostatic design stress in units of 100 psi with any decimal figures dropped. When the design stress code contains less than two figures, a cipher is used before the number. Example: PE2306, PE3406, PE3408, etc.

3.1.9 *working pressure*—the maximum allowable pressure in the system. ASAE 5376 establishes this pressure shall not exceed 72 % of the pressure rating of the pipe in order to provide for surge protection.

## 4. Classification

4.1 *General*—This specification covers PE pipe made from four PE plastic materials in both controlled inside diameter with standard dimension ratios of SIDR 5.3, SIDR 7, SIDR 9, SIDR 11.5, SIDR 15, and SIDR 19 and controlled outside diameter with SDR 21, SDR 17, SDR 13.5, and SDR 11. The pressure rating is uniform for all nominal pipe sizes for a given PE pipe material and SDR/SIDR (see Table X1.1 and Appendix X1).

## 5. Materials

5.1 *General*—The polyethylenes 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.

5.2 *Basic Materials and Compound*—Basic material and plastic extrusion compound shall meet the requirements for one of three basic PE grades as defined in Specification D 1248, in which the requirements are based on short-term tests, or similar grades as defined in Specification D 3350 in which the requirements are based on both short-term and long-term tests.

5.3 *Hydrostatic Design Stresses*—This specification covers PE pipe made from PE plastics as defined by two hydrostatic design stresses developed on the basis of long-term tests and four standard thermoplastic pipe material designation codes (see Appendix X1).

5.4 *Rework Material*—Clean rework material, generated from the manufacturer's own pipe production, may be 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 of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other properties.

NOTE 1—Pipe meeting the requirements in Specifications D 2239 or D 3035 will meet all the requirements in this specification.

### 6.2 Dimensions and Tolerances:

#### 6.2.1 Controlling Diameter:

6.2.1.1 *Outside Diameter Controlled Pipe*—The outside diameters and tolerances shall be as shown in Table 1 when measured in accordance with 7.4 and 7.4.1.1.

6.2.1.2 *Inside Diameter Controlled Pipe*—The inside diameters and tolerances shall be as shown in Table 2 when measured in accordance with 7.4 and 7.4.1.2.

#### 6.2.2 Wall Thickness:

6.2.2.1 *Outside Diameter Controlled Pipe*—The wall thicknesses and tolerances shall be as shown in Table 3 when measured in accordance with 7.4 and 7.4.2.

6.2.2.2 *Inside Diameter Controlled Pipe*—The wall thicknesses and tolerances shall be as shown in Table 4 when measured in accordance with 7.4 and 7.4.2.

**TABLE 1 Outside Diameters and Tolerances for SDR-PR PE Plastic Pipe**

Nominal Pipe Size, in.	Outside Diameter, in.	Tolerances, in.
½	0.840	±0.004
¾	1.050	±0.004
1	1.315	±0.005
1¼	1.660	±0.005
1½	1.900	±0.006
2	2.375	±0.006
3	3.500	±0.008
4	4.500	±0.009
6	6.625	±0.011

**TABLE 2 Inside Diameters and Tolerances for SIDR-PR PE Plastic Pipe**

Nominal Pipe Size, in.	Average Inside Diameter, in.	Tolerances, in.
1/2	0.622	+0.010 -0.010
3/4	0.824	+0.010 -0.015
1	1.049	+0.010 -0.020
1 1/4	1.380	+0.010 -0.020
1 1/2	1.610	+0.015 -0.020
2	2.067	+0.015 -0.020
2 1/2	2.469	+0.015 -0.250
3	3.068	+0.015 -0.030
4	4.026	+0.015 -0.035
6	6.065	+0.020 -0.035

6.2.3 *Wall Thickness Range*—The wall thickness range of any cross section shall not exceed 12 % when measured in accordance with 7.4 and 7.4.3.

6.3 *Sustained Pressure*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D 1598 at the test pressures given in Table 5 when tested in accordance with 7.5.

6.4 *Burst Pressure*—The minimum burst pressures for PE plastic pipe shall be as given in Table 6 when determined in accordance with 7.6.

6.5 *Carbon Black*—The polyethylene pipe extrusion compound shall contain at least 2 % carbon black when tested in accordance with 7.7. For pipe produced by simultaneous multiple extrusion, this requirement shall apply to the outer layer.

6.6 *Elevated Temperature Sustained Pressure*—The average failure time must meet or exceed the specified minimum average failure time in Table 7 for both hoop stresses of a given pipe test category when tested in accordance with 7.9.

## 7. Test Methods

### 7.1 Conditioning:

7.1.1 *Qualification Tests*—Condition the test specimens at  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) in accordance with Procedure A of Methods D 618 for those tests where conditioning is required.

7.1.2 *Quality Control Tests*—Condition the test specimens at  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) for 4 h in air or 1 h in water.

7.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) 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 between the purchaser and seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

7.4 *Dimensions and Tolerances*—Any length of pipe may be used to determine the dimensions.

#### 7.4.1 Controlling Diameter:

7.4.1.1 With controlled outside diameter, measure the outside diameter and tolerances of the pipe in accordance with

Method D 2122. The tolerances for out-of-roundness shall apply only on pipe prior to shipment.

7.4.1.2 With controlled inside diameter, measure the inside diameter of the pipe with a tapered plug gage in accordance with Method D 2122.

7.4.2 *Wall Thickness*—Make micrometer measurements of the wall thickness in accordance with Method D 2122 to determine the minimum value. Measure the wall thickness at both ends of the pipe to the nearest 0.001 in. (0.02 mm).

7.4.3 *Wall Thickness Range*—The wall thickness range of any cross section shall not exceed 12 % when measured in accordance with Method D 2122.

7.5 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at two controlled temperatures under the pressures given in Table 3, twelve specimens of pipe, each specimen at least ten times the nominal diameter in length, but not less than 10 in. (250 mm) nor more than 3 ft (1000 mm) between end closures and containing the permanent marking on the pipe. Test six specimens at each temperature. Maintain the specimens at the pressures indicated for the appropriate temperature for a period of 1000 h. Hold the pressure as closely as possible, but within  $\pm 10$  psi ( $\pm 70$  kPa). Prior to pressurization, condition the specimens for at least 2 h at within  $\pm 2^\circ\text{C}$  of the specified test temperatures. Maintain the test temperature within  $\pm 2^\circ\text{C}$  of the specified temperature. Test in accordance with Test Method D 1598, except maintain the pressure at the values given in Table 3 for 1000 h. Failure of two of the six specimens tested at either temperature constitutes failure of the test. Failure of one of six specimens tested at either temperature is cause for retest of six additional specimens at that temperature. Failure of one of six specimens tested at either temperature in retest constitutes failure in the test. Failure of the pipe shall be in accordance with Test Method D 1598.

7.6 *Burst Pressure*—The test equipment, procedures and failure definitions shall be as specified in Test Method D 1599. In addition, the failure must be ductile.

7.7 *Carbon Black*—Determine in duplicate the carbon black content of the pipe, in accordance with Test Method D 1603. The average value shall meet the requirements of 6.5.

7.8 *Density*—Determine the density of the pipe compound in accordance with Test Method D 1505, using three specimens. Calculate the density of the PE base resin (uncolored PE) in the pipe compound as follows:

$$D_R = D_P - 0.0044C \quad (5)$$

where:

$D_R$  = average density of resin,  $\text{g}/\text{cm}^3$ ,  
 $D_P$  = density of pipe compound,  $\text{g}/\text{cm}^3$ , and  
 $C$  = weight percent of carbon black.

7.9 *Elevated Temperature Test*—Determine pipe test category in Table 7 for a given piping material. Base resin melt index is determined in accordance with Test Method D 1238 and base resin density is determined in accordance with Test Method D 1505. Prepare at least three test specimens as in 7.5. Test at  $176^\circ\text{F}$  ( $80^\circ\text{C}$ ) and the hoop stress ( $S$ ) specified in Table 7 for the given pipe category in accordance with Test Method

**TABLE 3 Wall Thicknesses and Tolerances<sup>A</sup> for SDR-PR PE Plastic Pipe with Controlled Outside Diameters**

Nominal Pipe Size, in.	SDR 21		SDR 17		SDR 13.5		SDR 11	
	Minimum, in.	Tolerance, in.	Minimum, in.	Tolerance, in.	Minimum, in.	Tolerance, in.	Minimum, in.	Tolerance, in.
½	0.062 <sup>B</sup>	+0.020	0.062 <sup>B</sup>	+0.020	0.062	+0.020	0.076	+0.020
¾	0.062 <sup>B</sup>	+0.020	0.062	+0.020	0.078	+0.020	0.095	+0.021
1	0.062	+0.020	0.077	+0.020	0.097	+0.020	0.119	+0.026
1¼	0.079	+0.020	0.098	+0.020	0.123	+0.020	0.151	+0.026
1½	0.090	+0.020	0.112	+0.020	0.141	+0.020	0.173	+0.026
2	0.113	+0.020	0.140	+0.020	0.176	+0.021	0.216	+0.026
3	0.167	+0.020	0.206	+0.025	0.259	+0.031	0.318	+0.038
4	0.214	+0.026	0.264	+0.032	0.333	+0.040	0.409	+0.049
6	0.315	+0.038	0.390	+0.047	0.491	+0.059	0.602	+0.068

<sup>A</sup> The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any given cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

<sup>B</sup> Not minimum for the indicated SDR but minimum allowed for any pressure rating for outside diameter controlled pipe.

**TABLE 4 Wall Thicknesses and Tolerances for SDR-PR PE Plastic Pipe with Controlled Inside Diameter Wall Thickness<sup>A</sup>, in.**

Nominal Pipe Size, in.	SIDR 19		SIDR 15		SIDR 11.5		SIDR 9		SIDR 7		SIDR 5.3	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
½	0.060 <sup>B</sup>	+0.020	0.060 <sup>B</sup>	+0.020	0.060 <sup>B</sup>	+0.020	0.069	+0.020	0.089	+0.020	0.117	+0.020
¾	0.060 <sup>B</sup>	+0.020	0.060 <sup>B</sup>	+0.020	0.072	+0.020	0.092	+0.020	0.118	+0.020	0.155	+0.020
1	0.060 <sup>B</sup>	+0.020	0.070	+0.020	0.091	+0.020	0.117	+0.020	0.150	+0.020	0.198	+0.024
1¼	0.073	+0.020	0.092	+0.020	0.120	+0.020	0.153	+0.020	0.197	+0.024	0.260	+0.031
1½	0.085	+0.020	0.107	+0.020	0.140	+0.020	0.179	+0.020	0.230	+0.028	0.304	+0.036
2	0.109	+0.020	0.138	+0.020	0.180	±0.022	0.230	+0.028	0.295	+0.035	0.390	+0.047
2½	0.130	+0.020	0.165	+0.020	0.215	+0.025						
3	0.162	+0.020	0.205	+0.020	0.267	+0.032						
4	0.212	+0.025	0.268	+0.032	0.350	+0.042						
6	0.319	+0.038	0.404	+0.048	0.527	+0.063						

<sup>A</sup> The 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.

<sup>B</sup> Not minimum for the indicated SIDR but minimum allowed for any pressure rating for inside diameter controlled pipe.

**TABLE 5 Sustained Pressure Test Conditions for Water for SDR and SIDR Plastic Pipe**

Standard Dimension Ratio		Pressure Required for Test <sup>A</sup>							
		73°F (23°C)				100°F (38°C)			
		PE 3408		PE 2306 PE 2406	PE 3306 PE 3406	PE 3408		PE 2306 PE 2406 PE 3306 PE 3406	
SDR	SIDR	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)
...	5.3	...	...	420	(2.90)	420	(2.90)	340	(2.48)
...	7	400	(2.76)	330	(2.28)	330	(2.28)	270	(1.86)
...	9	320	( )	265	(1.83)	265	(1.83)	215	(1.48)
11	...	...	...	265	(1.83)	265	(1.83)	215	(1.48)
...	11.5	255	(1.77)	210	(1.45)	210	(1.45)	170	(1.17)
13.5	...	255	(1.77)	210	(1.45)	210	(1.45)	170	(1.17)
...	15	200	(1.38)	165	(1.14)	165	(1.14)	135	(0.93)
17	...	200	(1.38)	165	(1.14)	165	(1.14)	135	(0.93)
...	19	160	(1.10)	...	...	130	(0.90)	...	...
21	...	160	(1.10)	...	...	130	(0.90)	...	...

<sup>A</sup>The fiber stresses used to derive these test pressures are:

	73°F (23°C)		100°F (38°C)	
	psi	(MPa)	psi	(MPa)
PE 3408	1600	(11.03)	1320	(9.10)
PE 2306, PE 2406, PE 3306	1320	(9.10)	1070	(7.38)
PE 3406				