



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

This standard is issued under the fixed designation F771; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers 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:<sup>2</sup>

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<sup>2</sup>

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2239 Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter

D2609 Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe

D2683 Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing

D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products

D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

D3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

### 2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>3</sup>

### 2.3 Military Standard:

MIL-STD-129 Marking for Shipment and Storage<sup>3</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *General*—Nomenclature is in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, 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.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water.

Current edition approved Aug. 1, 2005. Published August 2005. Originally approved in 1982. Last previous edition approved in 1999 as F771 – 99<sup>e1</sup>. DOI: 10.1520/F0771-99R05.

<sup>2</sup> 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.

<sup>3</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 D1248 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 D1248, in which the requirements are based on short-term tests, or similar grades as defined in Specification D3350 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 D2239 or D3035 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.
1/2	0.840	±0.004
3/4	1.050	±0.004
1	1.315	±0.005
1 1/4	1.660	±0.005
1 1/2	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.
½	0.622	+0.010 -0.010
¾	0.824	+0.010 -0.015
1	1.049	+0.010 -0.020
1¼	1.380	+0.010 -0.020
1½	1.610	+0.015 -0.020
2	2.067	+0.015 -0.020
2½	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 D1598 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 D1238 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 D2122. 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 D2122.

7.4.2 *Wall Thickness*—Make micrometer measurements of the wall thickness in accordance with Method D2122 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 D2122.

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 D1598, 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 D1598.

7.6 *Burst Pressure*—The test equipment, procedures and failure definitions shall be as specified in Test Method D1599. 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 D1603. 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 D1505, 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 D1238



**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.
1/2	0.062 <sup>B</sup>	+0.020	0.062 <sup>B</sup>	+0.020	0.062	+0.020	0.076	+0.020
3/4	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
1 1/4	0.079	+0.020	0.098	+0.020	0.123	+0.020	0.151	+0.026
1 1/2	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 SIDR-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
1/2	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
3/4	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
1 1/4	0.073	+0.020	0.092	+0.020	0.120	+0.020	0.153	+0.020	0.197	+0.024	0.260	+0.031
1 1/2	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
2 1/2	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)					
	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	(2.21)	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)

and base resin density is determined in accordance with Test Method **D1505**. Prepare at least three test specimens as in **7.5**. Test at 176°F (80°C) and the hoop stress (*S*) specified in **Table 7** for the given pipe category in accordance with Test Method

**D1598**. Two of three specimens must meet or exceed the specified minimum average failure time. Use water as internal medium.