Attachment C

List of Relevant Standards for Polyethylene Pipe for Nuclear Piping for – Safety and Non-Safety Related Applications

1. ASTM D-3035-03, Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
2. ASTM D-3261-03, Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
3. ASTM D-3350-05, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
4. ASTM F-714-03, Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter
5. ASTM F-1055- 98, Standard Specification for Electro fusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
6. ASTM F-2206-02, Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock
7. ASTM F1473-07 Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins.
8. D1598-02 Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure.
9. F1474-98 Standard Test Method for Slow Crack Growth Resistance of Notched Polyethylene Plastic Pipe (includes Research Report on Round Robin Testing from ASTM).
10. ASTM D2657-07 Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings.
11. TR-33 Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe

Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter[1]

This standard is issued under the fixed designation D 3035; 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 thermoplastic pipe dimension ratios based on outside diameter and pressure rated for water (see Appendix X1). 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. Methods of marking are also given.

1.2 All pipes produced under this specification may be used for the transport of water, industrial process liquids, effluents, slurries, municipal sewage, etc. The user should consult the manufacturer to determine whether the material being transported is compatible with polyethylene pipe and will not affect the service life beyond limits acceptable to the user.

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

1.4 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:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 792 Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement[3]

D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[3]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[3]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[4]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 1603 Test Method for Carbon Black in Olefin Plastics[3]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2290 Test Method for Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method[3]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[3]

D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

2.2 *NSF International Standards:*

ANSI/NSF Standard No. 14 for Plastic Piping Components and Related Materials[5]

ANSI/NSF Standard No. 61 for Drinking Water System Components—Health Effects[5]

2.3 *PPI Documents:*

TR-4 Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe[6]

TR-9 Recommended Design Factors for Thermoplastic Pressure Pipe[6]

3. Terminology

3.1 Definitions—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

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[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.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.03.

[4] *Annual Book of ASTM Standards*, Vol 08.04.

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

[6] Available from the Plastics Pipe Institute, Inc., 1825 Connecticut Ave., NW, Suite 680 Washington, DC 20009.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *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.

3.2.2 *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.

3.2.3 *relation between dimension ratio, hydrostatic design stress, and pressure rating*—the following expression, commonly known as the ISO equation,[7] is used in this specification to relate dimension ratio, hydrostatic design stress, and pressure rating:

$$2S/P = R - 1 \text{ or } 2S/P = (D_0/t) - 1 \quad (1)$$

where:

S = hydrostatic design stress, psi (MPa),
P = pressure rating, psi (MPa),
D_0 = average outside diameter, in. (mm)
t = minimum wall thickness, in. (mm), and,
R = thermoplastic pipe dimension ratio (D_0/t for PE pipe).

3.2.4 *thermoplastic pipe dimension ratio (DR)*—the ratio of pipe diameter to wall thickness. For PE pipe covered by this specification it is calculated by dividing the average outside diameter of the pipe, in inches, by the minimum wall thickness, in inches. If the wall thickness calculated by this formula is less than 0.062 in. (1.6 mm), it shall be arbitrarily increased to 0.062 in.

3.2.5 *thermoplastic pipe materials designation code*—the polyethylene pipe materials designation code shall consist of the abbreviation PE for the type of plastics, 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 zero 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 three PE plastic pipe materials in various dimension ratios and water pressure ratings.

4.2 *Thermoplastic Pipe Dimension Ratios* (DR)—This specification covers PE pipe in various dimension ratios such as, but not limited to, DR 11, DR 13.5, DR 17, and DR 21. The pressure rating is uniform for all nominal sizes of pipe for a given PE pipe material and DR. (See Table X1.1.)

4.3 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable in engineered products when mutually agreed upon by the customer and manufacturer if (*1*) the pipe is manufactured from plastic compounds meeting the material requirements of this specification and (*2*) the strength and design requirements are calculated on the same basis as those used in this specification.

5. Materials

5.1 *Classification*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall be classified in accordance with Specification D 3350 and as shown in Table 1.

NOTE 1—Piping intended for use in the transport of potable water should be evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation should be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in ANSI/NSF Standard No. 14 or ANSI/NSF Standard No. 61. The seal or mark of the laboratory making the evaluation should be included on the piping.

NOTE 2—Pipe users should consult with the pipe manufacturer about the outdoor exposure life of the product under consideration.

5.2 *Long-term Property Requirements*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall meet or exceed the long-term property requirements in Table 2.

5.3 *HDB Listing*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall be listed in PPI TR-4 with HDB ratings in accordance with Table 2.

5.4 *Rework Material*—Clean, rework material having the same classification and generated from the manufacturer's own pipe production, may be used by the same manufacturer, as long as the pipe produced meets all of 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*:

6.2.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 3 when measured in

TABLE 1 Specification D 3350 Cell Classifications for Polyethylene Pipe Materials

PE Material Designation Code	PE 1404	PE 2406	PE 3408
Physical Property:		Cell Classifications	
Density	1	2	3
Melt Index	2	3 or 4	3 or 4
Flexural Modulus	3	3 or 4	4 or 5
Tensile Strength at Yield	1	3 or 4	4 or 5
Slow Crack Growth Resistance	1[A]	6[B]	6[B]
Hydrostatic Design Basis	1	3	4
Color and UV Stabilizer[C]	C	C or E	C or E

[A] Test Method D 1693 ESCR.
[B] Test Method F 1473 PENT.
[C] Classification E compounds shall have sufficient UV stabilizer to protect pipe from deleterious effects due to continuous outdoor exposure during shipping and unprotected outdoor storage for up to 18 months. Pipe produced from Classification E compounds is not suitable for continuous use in exposed outdoor applications. Classification C and E compounds shall have sufficient antioxidants to meet requirements in Specification D 3350. Classification C compounds shall contain 2 to 3 % carbon black when tested in accordance with Test Method D 1603.

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

TABLE 2 Long-Term Property Requirements

PE Material Designation Code	Long-term Property in Accordance with Test Method D 2837[A]
PE 1404	HDB of 800 psi at 73°F (5.52 MPa at 23°C)
PE 2406	HDB of 1250 psi at 73°F (8.62 MPa at 23°C)
PE 3408	HDB of 1600 psi at 73°F (11.03 MPa at 23°C)
PE 2406 and PE 3408	Minimum HDB of 630 psi at 140°F (4.34 MPa at 60°C)

[A] The hydrostatic design basis shall be established using water or air as the pressurizing fluid.

TABLE 3 Outside Diameters and Tolerances for DR-PR PE Plastic Pipe

Nominal Pipe Size, in.	Outside Diameter, in. (mm)	Tolerances, in. (mm)
½	0.840 (21.34)	±0.004 (0.10)
¾	1.050 (26.7)	±0.004 (0.10)
1	1.315 (33.4)	±0.005 (0.13)
1¼	1.660 (42.2)	±0.005 (0.13)
1½	1.900 (48.3)	±0.006 (0.15)
2	2.375 (60.3)	±0.006 (0.15)
3	3.500 (88.9)	±0.008 (0.20)
4	4.500 (114.3)	±0.009 (0.23)
6	6.625 (168.28)	±0.011 (0.28)
8	8.625 (219.08)	±0.013 (0.33)
10	10.750 (273.05)	±0.015 (0.38)
12	12.750 (323.85)	±0.017 (0.43)
14	14.000 (355.60)	±0.063 (1.60)
16	16.000 (406.40)	±0.072 (1.83)
18	18.000 (457.20)	±0.081 (2.06)
20	20.000 (508.00)	±0.090 (2.29)
22	22.000 (558.80)	±0.099 (2.51)
24	24.000 (609.60)	±0.108 (2.74)

accordance with Test Method D 2122. For diameters not shown in Table 3, the tolerances shall be the same percentage of the outside diameter as those for the closest listed diameter.

6.2.2 *Wall Thicknesses*—The wall thicknesses and tolerances shall be as shown in Table 4 when measured in accordance with Test Method D 2122. For wall thicknesses (DRs) not shown in Table 4, the tolerances shall be the same percentage of the calculated minimum wall as for the closest listed minimum wall thickness.

6.2.3 *Wall Thickness Range*—The wall thickness range shall be within 12 % when measured in accordance with Test Method D 2122.

6.3 *Short-term Properties*—Specimens of pipe shall be tested in accordance with either Test Method D 1599 or Test Method D 2290. The test method used, Test Method D 1599 or Test Method D 2290, is determined by the pipe size and the availability of appropriate test equipment. Test Method D 1599 is generally used for 4 in. (114 mm) and smaller sizes and Test Method D 2290 for 2-in (60 mm) and larger sizes. Short-term hoop stress and failure mode data is provided by either test.

6.3.1 *Burst Pressure*—The minimum burst pressure for PE plastic pipe shall be as given in Table 5, when determined in accordance with Test Method D 1599 and 7.6, using a minimum fiber stress of 1250 psi (8.62 MPa) for PE 1404 and 2520 psi (17.37 MPa) for PE 2406 and PE 3408. The failure mode shall be ductile.

6.3.2 *Apparent Ring Tensile Strength*—The minimum apparent ring tensile strength at yield shall be 1250 psi (8.62 MPa) for PE 1404 and 2520 psi (17.37 MPa) for PE 2406 and PE 3408 when tested in accordance with Test Method D 2290, Procedure B and 7.7. The failure shall be ductile.

6.4 *Sustained Pressure at Ambient and Elevated Temperature*—Pipes made from PE 2406 and PE 3408 shall be tested in accordance with 7.7 at the pressures and temperatures specified in Table 7. Tests may be conducted at either stress and on any size, but tests conducted on 6 in. (168 mm) nominal size pipe shall be considered representative of all pipe sizes. If ductile failures occur at the higher stress, repeat testing at the lower stress.

7. Test Methods

7.1 *Conditioning*—Condition the test specimens for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 73 ± 3.6°F (23 ± 2°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 by the purchaser and the seller. In case of no prior agreement, random samples as selected by the testing laboratory shall be deemed adequate.

7.4 *Ambient Temperature Sustained Pressure Test*—Select six specimens of pipe at random and test each specimen individually with water at controlled temperatures under the pressures given in Table 6. Each specimen shall be at least ten times the nominal diameter in length, but not less than 10 in. (250 mm) or more than 3 ft (1000 mm) between end closures and containing the permanent marking on the pipe. Condition the specimens for at least 2 h at 73 ± 3.6°F (23 ± 2°C). Test for the minimum failure time specified in Table 6 in accordance with Test Method D 1598, at the pressure and temperature values given in Table 7. Maintain the specimens at the pressures indicated ±10 psi (±70 kPa) and the temperatures specified ± 3.6°F (± 2°C). Failure of two of the six specimens tested constitutes failure of the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of six specimens tested in retest constitutes failure in the test. Failure of the pipe test specimen shall be as defined in Test Method D 1598.

7.5 *Elevated Temperature Sustained Pressure Test*—Prepare at least three test specimens as specified in 7.4. Using water as internal medium, test at 176°F (80°C) and the hoop stress (*S*) specified in Table 7 for the given pipe material in accordance with Test Method D 1598. Two of three specimens must meet or exceed the specified minimum average failure time.

7.6 *Hydrostatic Burst Pressure*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D 1599.

7.7 *Apparent Ring Tensile Strength at Yield*—The method and test equipment shall be as specified in Test Method D 2290, Procedure B. Test a minimum of five specimens.

8. Retest and Rejection

8.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting

TABLE 4 Wall Thicknesses and Tolerances[A] for DR-PR PE Plastic Pipe

Nominal Pipe Size, IPS, in.	DR 32.5				DR 26				DR 21				DR 17				DR 15.5			
	Mininum		Tolerance		Minimum		Tolerance		Minimum		Tolerance		Minimum		Tolerance		Minimum		Tolerance	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
½	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)
¾	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.068	(1.73)	0.020	(0.51)
1	0.062	(1.57)	0.020	(0.51)	0.062	(1.57)	0.020	(0.51)	0.063	(1.60)	0.020	(0.51)	0.077	(1.96)	0.020	(0.51)	0.084	(2.13)	0.020	(0.51)
1¼	0.062	(1.57)	0.020	(0.51)	0.064	(1.63)	0.020	(0.51)	0.079	(2.01)	0.020	(0.51)	0.098	(2.49)	0.020	(0.51)	0.107	(2.72)	0.020	(0.51)
1½	0.062	(1.57)	0.020	(0.51)	0.073	(1.85)	0.020	(0.51)	0.090	(2.29)	0.020	(0.51)	0.112	(2.84)	0.020	(0.51)	0.123	(3.12)	0.020	(0.51)
2	0.073	(1.85)	0.020	(0.51)	0.091	(2.31)	0.020	(0.51)	0.113	(2.87)	0.020	(0.51)	0.140	(3.56)	0.020	(0.51)	0.153	(3.89)	0.020	(0.51)
3	0.108	(2.74)	0.020	(0.51)	0.135	(3.43)	0.020	(0.51)	0.167	(4.24)	0.020	(0.51)	0.206	(5.23)	0.025	(0.64)	0.226	(5.74)	0.027	(0.69)
4	0.138	(3.51)	0.020	(0.51)	0.173	(4.39)	0.021	(0.53)	0.214	(5.44)	0.026	(0.66)	0.265	(6.73)	0.032	(0.81)	0.290	(7.37)	0.035	(0.89)
5	0.171	(4.34)	0.021	(0.53)	0.214	(5.44)	0.026	(0.66)	0.265	(6.73)	0.032	(0.81)	0.327	(8.31)	0.039	(0.99)	0.359	(9.12)	0.043	(1.09)
6	0.204	(5.18)	0.024	(0.61)	0.255	(6.48)	0.031	(0.79)	0.315	(8.00)	0.038	(0.97)	0.390	(9.91)	0.047	(1.19)	0.427	(10.85)	0.051	(1.30)
8	0.265	(6.73)	0.032	(0.81)	0.332	(8.43)	0.040	(1.02)	0.411	(10.44)	0.049	(1.24)	0.507	(12.88)	0.061	(1.55)	0.556	(14.12)	0.067	(1.70)
10	0.331	(8.41)	0.040	(1.02)	0.413	(10.49)	0.050	(1.27)	0.512	(13.00)	0.061	(1.55)	0.632	(16.05)	0.076	(1.93)	0.694	(17.63)	0.083	(2.11)
12	0.392	(9.96)	0.047	(1.19)	0.490	(12.45)	0.059	(1.50)	0.607	(15.42)	0.073	(1.85)	0.750	(19.05)	0.090	(2.29)	0.823	(20.90)	0.099	(2.51)
14	0.431	(10.95)	0.052	(1.32)	0.538	(13.67)	0.065	(1.65)	0.667	(16.94)	0.080	(2.03)	0.824	(20.93)	0.099	(2.51)	0.903	(22.94)	0.108	(2.74)
16	0.492	(12.50)	0.059	(1.50)	0.615	(15.62)	0.074	(1.88)	0.762	(19.35)	0.091	(2.31)	0.941	(23.90)	0.113	(2.87)	1.032	(26.21)	0.124	(3.15)
18	0.554	(14.07)	0.066	(1.68)	0.692	(17.58)	0.083	(2.11)	0.857	(21.77)	0.103	(2.62)	1.059	(26.90)	0.127	(3.23)	1.161	(29.49)	0.139	(3.53)
20	0.615	(15.62)	0.074	(1.88)	0.769	(19.53)	0.092	(2.34)	0.952	(24.18)	0.114	(2.90)	1.176	(29.87)	0.141	(3.58)	1.290	(32.77)	0.155	(3.94)
22	0.677	(16.94)	0.081	(2.06)	0.846	(21.49)	0.102	(2.59)	1.048	(26.62)	0.126	(3.20)	1.294	(32.87)	0.155	(3.94)	1.419	(36.04)	0.170	(4.32)
24	0.738	(18.75)	0.089	(2.26)	0.923	(23.44)	0.111	(2.82)	1.143	(29.03)	0.137	(3.48)	1.412	(35.86)	0.169	(4.29)	1.548	(39.32)	0.186	(4.72)
Nominal Pipe Size, IPS, in.	DR 13.5				DR 11				DR 9.3				DR 9				DR 7			
	Mininum		Tolerance		Minimum		Tolerance		Minimum		Tolerance		Minimum		Tolerance		Minimum		Tolerance	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
½	0.062	(1.57)	0.020	(0.51)	0.076	(1.93)	0.020	(0.51)	0.090	(2.29)	0.020	(0.51)	0.093	(2.36)	0.020	(0.51)	0.120	(3.05)	0.020	(0.51)
¾	0.078	(1.98)	0.020	(0.51)	0.095	(2.41)	0.020	(0.51)	0.113	(2.87)	0.020	(0.51)	0.117	(2.97)	0.020	(0.51)	0.150	(3.81)	0.020	(0.51)
1	0.097	(2.46)	0.020	(0.51)	0.120	(3.05)	0.020	(0.51)	0.141	(3.58)	0.020	(0.51)	0.146	(3.71)	0.020	(0.51)	0.188	(4.78)	0.023	(0.58)
1¼	0.123	(3.12)	0.020	(0.51)	0.151	(3.84)	0.020	(0.51)	0.178	(4.52)	0.021	(0.53)	0.184	(4.67)	0.022	(0.56)	0.237	(6.02)	0.028	(0.71)
1½	0.141	(3.58)	0.020	(0.51)	0.173	(4.39)	0.021	(0.53)	0.204	(5.18)	0.024	(0.61)	0.211	(5.36)	0.025	(0.64)	0.271	(6.88)	0.033	(0.84)
2	0.176	(4.47)	0.021	(0.53)	0.216	(5.49)	0.026	(0.66)	0.255	(6.48)	0.031	(0.79)	0.264	(6.71)	0.032	(0.81)	0.339	(8.61)	0.041	(1.04)
3	0.259	(6.58)	0.031	(0.79)	0.318	(8.08)	0.038	(0.97)	0.376	(9.55)	0.045	(1.14)	0.389	(9.88)	0.047	(1.19)	0.500	(12.70)	0.060	(1.52)
4	0.333	(8.46)	0.040	(1.02)	0.409	(10.39)	0.049	(1.24)	0.484	(12.29)	0.058	(1.47)	0.500	(12.70)	0.060	(1.52)	0.643	(16.33)	0.077	(1.96)
5	0.412	(10.46)	0.049	(1.24)	0.506	(12.85)	0.061	(1.55)	0.598	(15.19)	0.072	(1.83)	0.618	(15.70)	0.074	(1.88)	0.795	(20.19)	0.095	(2.41)
6	0.491	(12.47)	0.059	(1.50)	0.602	(15.29)	0.072	(1.83)	0.712	(18.08)	0.085	(2.16)	0.736	(18.69)	0.088	(2.24)	0.946	(24.03)	0.114	(2.90)
8	0.639	(16.23)	0.077	(1.96)	0.784	(19.91)	0.094	(2.39)	0.927	(23.55)	0.111	(2.82)	0.958	(24.33)	0.115	(2.92)	1.232	(31.29)	0.147	(3.73)
10	0.796	(20.22)	0.096	(2.44)	0.977	(24.82)	0.117	(2.97)	1.156	(29.36)	0.139	(3.53)	1.194	(30.33)	0.143	(3.63)	1.536	(39.01)	0.184	(4.67)
12	0.944	(23.98)	0.113	(2.87)	1.159	(29.44)	0.139	(3.53)	1.371	(34.82)	0.165	(4.19)	1.417	(35.99)	0.170	(4.32)	1.821	(46.25)	0.219	(5.56)
14	1.037	(26.34)	0.124	(3.15)	1.273	(32.33)	0.153	(3.89)	1.505	(38.23)	0.181	(4.60)	1.556	(39.52)	0.187	(4.75)	2.000	(50.80)	0.240	(6.10)
16	1.185	(30.10)	0.142	(3.61)	1.455	(36.96)	0.175	(4.45)	1.720	(43.69)	0.206	(5.23)	1.778	(45.16)	0.213	(5.41)	2.286	(58.06)	0.274	(6.96)
18	1.333	(33.86)	0.160	(4.06)	1.636	(41.55)	0.196	(4.98)	1.935	(49.15)	0.232	(5.89)	2.000	(50.80)	0.240	(6.10)	2.571	(65.30)	0.309	(7.85)
20	1.481	(37.62)	0.178	(4.52)	1.818	(46.18)	0.218	(5.54)	2.151	(54.64)	0.258	(6.55)	2.222	(56.44)	0.267	(6.78)	2.857	(72.57)	0.343	(8.71)
22	1.630	(41.40)	0.196	(4.98)	2.000	(50.80)	0.240	(6.10)	2.366	(60.10)	0.284	(7.21)	2.444	(62.08)	0.293	(7.44)	3.143	(79.83)	0.377	(9.58)
24	1.778	(45.16)	0.213	(5.41)	2.182	(55.42)	0.262	(6.65)	2.581	(65.56)	0.310	(7.87)	2.667	(67.74)	0.320	(8.13)	3.429	(87.10)	0.411	(10.44)

[A] The minimum is the lowest wall thickness of the pipe allowable 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.

tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in the specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

9. Marking

9.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft (1.5 m):

9.1.1 Nominal pipe size (for example, 2 in. IPS),

9.1.2 Type of plastic pipe material in accordance with the designation code given in 3.2.5 (for example, PE3408),

9.1.3 Thermoplastic pipe dimension ratio, in accordance with the designation code given in 4.2 (for example, DR 11), or the pressure rating, in pounds force per square inch (or pascals), for water at 73°F (23°C) shown as the number followed by psi (kPa) (for example, 100 psi (690 kPa)), except that when intended for pressure application, the pressure rating shall be shown (for example, 100 psi (690 kPa)). When the indicated pressure rating is lower than that calculated in accordance with 3.2.4 (see Appendix X1) the SDR shall also be included in the marking code,

9.1.4 Specification D 3035, with which the pipe complies.

9.1.5 Manufacturer's name (or trademark) and code.

9.1.6 Pipe intended for transporting potable water shall also include the seal of an accredited laboratory (Note 1).

TABLE 5 Burst Pressure Requirements for Water at 73°F (23°C) for DR-PR PE Plastic Pipe

Dimension Ratio	Min Burst Pressure,[A] psi (MPa)			
	PE 2406 PE 3408		PE 1404	
	psi	(MPa)	psi	(MPa)
7	840	(5.79)	417	(2.87)
9	630	(4.34)	313	(2.16)
9.3	607	(4.19)	301	(2.08)
11	504	(3.47)	250	(1.72)
13.5	403	(2.78)	200	(1.38)
15.5	348	(2.40)	172	(1.19)
17	315	(2.13)	156	(1.08)
21	252	(1.74)	125	(0.86)
26	202	(1.39)	100	(0.69)
32.5	160	(1.10)	79	(0.55)

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	(MPa)
PE 2406 and PE 3408	2520	(17.37)
PE 1404	1250	(8.62)

NOTE 3—Manufacturers using the seal of approval of an accredited laboratory must obtain prior authorization from the laboratory concerned.

TABLE 6 Apparent Tensile Strength at Yield of Ring Specimens Cut from Pipe

Material	psi	(MPa)
PE 3408 and PE 2406	2520	(17.37)
PE 1404	1250	(8.62)

9.2 *Using Color to Identify Piping Service*— It is not mandatory to use color to identify piping service, but when color is applied expressly to identify piping service, such as with stripes , a color shell or a solid collor, blue is used for potable water; green is used for sewer; and purple (violet, lavender) is used for reclaimed water.

10. Quality Assurance

10.1 When the product is marked with this designation, D 3035, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

TABLE 7 Sustained Pressure Test Conditions, Requirements and Pressures[A]

Pipe Material	Minimum Hours Before Failure at 73°F (23°C)			Minimum Average Hours to Failure at 176°F (80°C)		
	S = 1600 psi (11 MPa)	S = 1320 psi (9.1 MPa)	S = 800 psi (5.5 MPa)	S = 725 psi (5 MPa)	S = 580 psi (4 MPa)	S = 435 psi (3 MPa)
PE 1404			1000		80	150
PE 2406		1000		60	150	
PE 3408	1000			60	150	

Material	Temperature, °F (°C)	Stress, S, psi (MPa)	Dimension Ratio									
			7	9	9.3	11	13.5	15.5	17	21	26	32.5
			Pressure Required for test, psi (MPa)									
PE 1404	73 (23)	800 (5.5)	267 (1.84)	200 (1.38)	193 (1.33)	160 (1.10)	128 (0.88)	110 (0.76)	100 (0.69)	80 (0.55)	64 (0.44)	51 (0.35)
	176 (80)	580 (4)	193 (1.33)	145 (1.00)	140 (0.97)	116 (0.80)	93 (0.64)	80 (0.55)	73 (0.50)	58 (0.40)	46 (0.32)	37 (0.26)
	176 (80)	435 (3)	145 (1.00)	108 (0.75)	105 (0.72)	87 (0.60)	70 (0.48)	60 (0.41)	54 (0.38)	44 (0.30)	35 (0.24)	28 (0.19)
PE 2406	73 (23)	1320 (9.1)	440 (3.03)	330 (2.28)	318 (2.19)	264 (1.82)	211 (1.46)	182 (1.26)	165 (1.14)	132 (0.91)	106 (0.73)	84 (0.58)
	176 (80)	725 (5)	242 (1.67)	181 (1.25)	175 (1.21)	145 (1.00)	116 (0.80)	100 (0.69)	91 (0.63)	73 (0.50)	58 (0.40)	46 (0.32)
	176 (80)	580 (4)	193 (1.33)	145 (1.00)	140 (0.97)	116 (0.80)	93 (0.64)	80 (0.55)	73 (0.50)	58 (0.40)	46 (0.32)	37 (0.26)
PE 3408	73 (23)	1600 (11)	533 (3.68)	400 (2.76)	386 (2.66)	320 (2.21)	256 (1.77)	221 (1.52)	200 (1.38)	160 (1.10)	128 (0.88)	102 (0.70)
	176 (80)	725 (5)	242 (1.67)	181 (1.25)	175 (1.21)	145 (1.00)	116 (0.80)	100 (0.69)	91 (0.63)	73 (0.50)	58 (0.40)	46 (0.32)
	176 (80)	580 (4)	193 (1.33)	145 (1.00)	140 (0.97)	116 (0.80)	93 (0.64)	80 (0.55)	73 (0.50)	58 (0.40)	46 (0.32)	37 (0.26)

[A] Calculate internal pressure in accordance with the following formula:

$$P = \frac{2S}{\frac{D_o}{t} - 1}$$

where:

P = pressure, psig (MPa),
S = hoop stress, psi (MPa),
D_o = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

SUPPLEMENTARY REQUIREMENTS

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S1. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

APPENDIX

(Nonmandatory Information)

X1. PIPE PRESSURE RATINGS

TABLE X1.1 Thermoplastic Pipe Dimension Ratios (DR) and Water Pressure Ratings (PR) at 73°F (23°C) for DR-PR PE Plastic Pipe

Dimension Ratio	PE Pipe Materials[A]					
	PE 3408		PE 2406		PE 1404	
	Pressure Rating, psi (MPa)					
7	267	(1.84)	210	(1.45)	133	(0.92)
9	200	(1.38)	158	(1.09)	100	(0.69)
9.3	193	(1.33)	152	(1.05)	96	(0.66)
11	160	(1.10)	126	(0.87)	80	(0.55)
13.5	128	(0.88)	100	(0.69)	64	(0.44)
15.5	110	(0.76)	87	(0.60)	55	(0.38)
17	100	(0.69)	79	(0.54)	50	(0.34)
21	80	(0.55)	63	(0.43)	40	(0.28)
26	64	(0.44)	50	(0.34)	32	(0.22)
32.5	51	(0.35)	40	(0.28)	25	(0.17)

[A] See 3.2.5 for code designations. Pressure ratings determined using 0.50 design factor. Other design factors may be appropriate under certain conditions. See PPI TR-9.

X1.1 The pipe is rated for use with water at 73°F (23°C) at the maximum internal pressures shown in Table X1.1. Lower pressure ratings than those calculated in accordance with 3.2.3 may be recommended by the pipe manufacturer where pressure surges, elevated temperatures, or unusual installation conditions exist. Experience of the industry indicates that PE plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for a long period at these pressure ratings. The sustained pressure requirements (see 6.4) are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.2 The hydrostatic design stress recommended by the Plastics Pipe Institute are based on tests made on pipe ranging in size from ½ to 3 in. (12.7 to 50.8 mm).

Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing[1]

This standard is issued under the fixed designation D 3261; 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) butt fusion fittings for use with polyethylene pipe (IPS and ISO) and tubing (CTS). Included are requirements for materials, workmanship, dimensions, marking, sustained pressure, and burst pressure.

1.2 The values given in parentheses are provided for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[2]

D 1599 Test Method for Resistance to Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings [2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[2]

D 2513 Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings[2]

D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials [4]

F 412 Terminology Relating to Plastic Piping Systems[2]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[5]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[5]

2.4 *National Sanitation Foundation Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[6]

3. Terminology

3.1 Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

3.2 *dimension ratio (DR) for thermoplastic pipe*—the ratio of diameter to wall thickness. For this specification it is calculated by dividing the specified outside diameter by the specified wall thickness of the fitting at its area of fusion. DRs are rounded and do not calculate exactly.

4. Classification

4.1 *General*—This specification covers butt fusion fittings intended for use with polyethylene pipe and tubing.

4.1.1 Fittings covered by this specification are normally molded. Fittings may be machined from extruded or molded stock.

4.1.2 Fittings fabricated by thermal welding are not included in this specification.

4.1.3 Fittings intended for use in the distribution of natural gas or petroleum fuels shall also meet the requirements of Specification D 2513.

5. Ordering Information

5.1 When ordering fittings under this specification, the following should be specified:

5.1.1 Polyethylene compound (material designation or trade name)

5.1.2 Style of fitting (tee, 90° ell, and the like)

5.1.3 Size:

5.1.3.1 Nominal diameter.

5.1.3.2 CTS, IPS, or schedule.

5.1.3.3 Dimension ratio number or schedule number.

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[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

Current edition approved April 10, 2003. Published August 2003. Originally approved in 1973. Last previous edition approved in 1997 as D 3261 – 97.

[2] *Annual Book of ASTM Standards*, Vol 08.04.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

TABLE 1 Specification D 3350 Classification of Polyethylene Fittings Materials

For HDB of	1250 psi (8.6 MPa)	1600 psi (11 MPa)
Physical Properties and Cell Classification Limits are:		
Density (base resin)	2	3
Melt Index	3 or 4	3 or 4
Flexural Modulus	4 to 5	4 or 5 or 6
Tensile Strength	3 or 4	3 or 4 or 6
SCG Resistance[A]	4 or 6	4 or 6
HDB	3	4
Color and UV Stabilizer	C or E	C or E

[A]In accordance with the requirements of Specification D 2513 a 6 is required when fittings are intended for use in the distribution of natural gas or petroleum fuels.

6. Materials

6.1 *Basic Materials*—This specification covers fittings made from polyethylene plastics as defined in Specification D 3350.

NOTE 1—The Plastics Pipe Insitute has recommended a hydrostatic design stress of 630 psi (4.34 MPa) for pipe compounds designated as PE 2406 and 800 psi (5.51 MPa) for compounds designated as PE 3408.

6.2 *Rework Material*—Clean rework material generated from the manufacturer's own production may be used by the same manufacturer as long as the fittings produced conform to the requirements of this specification.

7. Requirements

7.1 *Dimensions and Tolerances*:

7.1.1 *Outside Diameter*—Nominal outside diameters of butt fusion fittings shall conform to the nominal iron pipe size (IPS) or copper tubing size (CTS) dimensions at area of fusion. These dimensions and tolerances shall be as shown in Table 2 and Table 3 of this specification.

TABLE 2 IPS Sizing System Outside Diameters and Tolerances for Fittings for Use with Polyethylene Pipe, in.

Nominal Pipe Size	Average Outside Diameter at Area of Fusion[A]	Tolerance
½	0.840	±0.008
¾	1.050	±0.008
1	1.315	±0.010
1 ¼	1.660	±0.010
1 ½	1.900	±0.010
2	2.375	±0.010
3	3.500	±0.012
4	4.500	±0.015
6	6.625	±0.018
8	8.625	±0.025
10	10.750	±0.027
12	12.750	±0.036
14	14.000	±0.063
16	16.000	±0.072
18	18.000	±0.081
20	20.000	±0.090
21.5	21.500	±0.097
22	22.000	±0.099
24	24.000	±0.108
28	28.000	±0.126
32	32.000	±0.144
36	36.000	±0.162
42	42.000	±0.189
48	48.000	±0.216

[A] Defined as measured ¼ to ½ in. (6.4 to 12.7 mm) from fitting outlet extremity.

TABLE 3 ISO Sizing System (ISO 161/1) Outside Diameters and Tolerances for Fit for Use with Polyethylene Pipe, mm

Nominal Pipe Size	Average Outside Diameter at Area of Fusion	
	Min	Max[A]
90	90.0	90.8
110	110.0	111.0
160	160.0	161.4
200	200.0	201.8
250	250.0	252.3
280	280.0	282.5
315	315.0	317.8
355	355.0	358.2
400	400.0	403.6
450	450.0	454.1
500	500.0	504.5
560	560.0	565.0
630	630.0	635.7
710	710.0	716.4
800	800.0	807.2
900	900.0	908.1
1000	1000.0	1009.0
1200	1200.0	1210.8
1400	1400.0	1412.6
1600	1600.0	1614.4

[A] Specified in ISO 3607.

7.1.2 *Inside Diameter (CTS Fittings Only)*—Inside diameters of butt fusion fittings for tubing at area of fusion shall conform to the dimensions of the tubing being joined. The dimensions and tolerances for the fittings are shown in Table 4.

7.1.3 *Wall Thickness*—The wall thicknesses of butt fusion fittings shall not be less than the minimum specified for the pipe or tubing. The wall thicknesses and tolerances at the area of fusion shall be as shown in Table 4, Table 5 and Table 6 of this specification.

7.1.4 *Measurements*—These shall be made in accordance with Test Method D 2122 for roundable pipe.

7.1.5 *Design Dimensions*—Overall fitting dimensions may be as preferred from a design standpoint by the manufacturer and accepted by the purchaser consistent with 7.1.3.

7.1.6 *Special Sizes*— Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable for engineered applications when mutually agreed upon by the customer and the manufacturer, if the fitting is manufactured from plastic compounds meeting the material requirements of this specification, and the strength and design requirements are calculated on the same basis as those used in this specification. For diameters not shown in Table 2 or Table 3, the tolerance shall be the same percentage as that shown in the corresponding tables for the next smaller listed size. Minimum wall thickness for these special sizes shall not be less than the minimum wall specified for the pipe or tubing the fitting is designed to be used with. The maximum wall thickness allowed shall not be greater than 20 % thicker than the specified minimum wall, and shall be determined by 10.4.3 of this specification.

7.2 *Pressure Test Requirements*:

7.2.1 *Short-Term Rupture Strength for Fittings* ½ to 12 in. and 90 to 315 mm, Nominal Diameter—The minimum short-term rupture strength of the fitting and fused pipe or tubing shall not be less than the minimum short-term rupture strength of the pipe or tubing in the system when tested in accordance

TABLE 4 Diameter, Wall Thickness, and Tolerances for Fittings for Use with Plastic Tubing

Tubing Type in. (mm)	Nominal Tubing Size, in.	Diameter at Area of Fusion[A]				Minimum Wall Thickness, in. (mm)
		Outside, in. (mm)		Inside, in. (mm)		
		Average	Tolerance	Average	Tolerance	
0.062 (1.57)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.495 (12.58)	±0.004 (±0.10)	0.062 (1.58)
	¾ CTS	0.875 (22.22)	± 0.010 (±0.26)	0.745 (18.92)	. . .	. . .
0.090 (2.29)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.437 (11.10)	±0.004 (±0.10)	0.090 (2.28)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.687 (17.44)	±0.004 (±0.10)	0.090 (2.28)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.937 (23.80)	±0.005 (±0.12)	0.090 (2.28)
	1 ¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.187 (30.14)	±0.005 (±0.12)	0.090 (2.28)
DR 11	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.715 (18.16)	±0.004 (±0.10)	0.077 (1.96)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.915 (23.24)	±0.005 (±0.12)	0.101 (2.56)
	1 ¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.125 (28.58)	±0.005 (±0.12)	0.121 (3.08)
DR 9.3	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.483 (12.26)	±0.004 (±0.10)	0.067 (1.70)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.679 (17.24)	±0.004 (±0.10)	0.094 (2.38)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.873 (22.18)	±0.005 (±0.12)	0.121 (3.08)
	1 ¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.069 (27.16)	±0.005 (±0.12)	0.148 (3.76)

[A] Defined as measured ¼ to ½ in. (6.4 to 12.7 mm) from fitting outlet extremity.

TABLE 5 IPS Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyethylene Pipe, in.[A,B,C]

Nominal Pipe Size	Minimum Wall Thickness									
	SCH 40	SCH 80	SDR 21	SDR 17	SDR 13.5	DR 10	DR 11.5	SDR 11	DR 9.3	SDR 9
½	0.109	0.147	. . .	. . .	. . .	. . .	. . .	0.076	0.090	. . .
¾	0.113	0.154	. . .	. . .	. . .	. . .	. . .	0.095	0.113	0.117
1	0.133	0.179	. . .	. . .	. . .	. . .	. . .	0.119	0.142	0.146
1¼	0.140	0.191	. . .	. . .	. . .	0.166	. . .	0.151	0.179	0.184
1 ½	0.145	0.200	. . .	. . .	. . .	. . .	. . .	0.173	0.204	0.211
2	0.154	0.218	. . .	. . .	. . .	. . .	. . .	0.216	0.256	0.264
3	0.216	0.300	. . .	. . .	0.259	. . .	0.305	0.318	0.377	0.389
4	0.237	0.337	. . .	0.264	0.333	. . .	0.392	0.409	0.484	0.500
6	0.280	0.432	0.316	0.390	0.491	. . .	0.576	0.603	0.713	0.736
8	0.322	. . .	0.410	0.508	0.639	. . .	0.750	0.785	0.928	0.958
10	0.365	. . .	0.511	0.633	0.797	. . .	0.935	0.978	1.156	1.194
12	0.406	. . .	0.608	0.750	0.945	. . .	1.109	1.160	1.371	1.417
14	. . .	. . .	0.667	0.824	. . .	. . .	. . .	1.273	1.505	1.556
16	. . .	. . .	0.762	0.941	. . .	. . .	. . .	1.455	1.720	1.778
18	. . .	. . .	0.857	1.059	. . .	. . .	. . .	1.636	1.935	2.000
20	. . .	. . .	0.952	1.176	. . .	. . .	. . .	1.818	2.151	2.222
21.5	. . .	. . .	1.024	1.265	. . .	. . .	. . .	. . .	. . .	. . .
22	. . .	. . .	1.048	1.294	. . .	. . .	. . .	2.000	2.366	2.444
24	. . .	. . .	1.143	1.412	. . .	. . .	. . .	2.182	2.581	. . .
28	. . .	. . .	1.333	1.647	. . .	. . .	. . .	2.545	. . .	. . .
32	. . .	. . .	1.524	1.882	. . .	. . .	. . .	2.909	. . .	. . .
36	. . .	. . .	1.714	2.118	. . .	. . .	. . .	. . .	. . .	. . .
42	. . .	. . .	2.000	2.471	. . .	. . .	. . .	. . .	. . .	. . .
48	. . .	. . .	2.286	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] Tolerance +20 %, −0 %.
[B] For those SDR groups having overlapping thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001 in.

with 10.5.3. These minimum pressures shall be as shown in Table 7 of this specification. Test specimens shall be prepared for testing in the manner described in 10.5.1 of this specification. The test equipment, procedures, and failures definitions shall be as specified in Test Method D 1599.

7.2.2 *Short-Term Strength for Fittings 14 to 48 in. and 355 to 1600 mm, Nominal Diameter*—Fittings shall not fail when tested in accordance with 10.5.3. The minimum pressure shall be as shown in Table 7 of this specification. Test specimens shall be prepared for testing in the manner described in 10.2 of this specification. The test equipment and procedures shall be as specified in Test Method D 1599.

7.2.3 *Sustained Pressure*—The fitting and fused pipe or tubing shall not fail, as defined in Test Method D 1598, when tested at the time, pressures, and test temperatures selected from test options offered in Table 8. The test specimens shall be prepared for testing in the manner prescribed in 10.5.1.

8. Workmanship, Finish, and Appearance

8.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

9. Sampling

9.1 Parts made for sale under this specification should be sampled at a frequency appropriate for the end use intended.

TABLE 6 ISO Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyethylene Pipe, mm[A,B,C]

Nominal Pipe Size	Minimal Wall Thickness					
	DR 41	DR 32.5	DR 26	DR 21	DR 17	DR 11
90	. . .	. . .	3.5	4.3	5.3	8.2
110	. . .	3.4	4.2	5.2	6.5	10.0
160	. . .	4.9	6.2	7.6	9.4	14.5
200	. . .	6.2	7.7	9.5	11.8	18.2
250	. . .	7.7	9.6	11.9	14.7	22.7
280	. . .	8.6	10.8	13.3	16.5	25.5
315	. . .	9.7	12.1	15.0	18.5	28.6
355	. . .	10.9	13.7	16.9	20.9	32.3
400	. . .	12.3	15.4	19.0	23.5	36.4
450	. . .	13.8	17.3	21.4	26.5	. . .
500	. . .	15.4	19.2	23.8	29.4	. . .
560	. . .	17.2	21.5	26.7	32.9	. . .
630	. . .	19.4	24.2	30.0	37.1	. . .
710	. . .	21.8	27.3	33.8	41.8	. . .
800	. . .	24.6	30.8	38.1	47.1	. . .
900	. . .	27.7	34.6	42.9	. . .	. . .
1000	24.4	30.8	38.5	47.6	. . .	. . .
1200	29.3	36.9	46.2	. . .	. . .	. . .
1400	34.1	43.1	. . .	. . .	. . .	. . .
1600	39.0	49.2	. . .	. . .	. . .	. . .

[A] Tolerance +20 %, −0 %.
[B] For those SDR groups having overlapped thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001.

TABLE 7 Burst Pressure Requirements at 73.4°F for Common Fitting Sizes[A]

Wall Thickness, DR, or Schedule	Nominal Diameter	Minimum Pressure, psi (MPa)
DR 7	ALL[B]	840 (5.793)
SDR 9	ALL[B]	630 (4.345)
DR 9.3	ALL[B]	610 (4.207)
SDR 11	ALL[B]	500 (3.448)
DR 11.5	ALL[B]	480 (3.310)
DR 15.5	ALL[B]	350 (2.414)
SDR 17	ALL[B]	320 (2.207)
SDR 21	ALL[B]	250 (1.724)
DR 26	ALL[B]	200 (1.390)
DR 32.5	ALL[B]	160 (1.103)
0.062 in. (1.575 mm)	½ CTS	555 (3.828)
0.062 in. (1.575 mm)	¾ CTS	380 (2.621)
0.062 in. (1.575 mm)	1 CTS	290 (2.000)
0.090 in. (2.286 mm)	½ CTS	850 (5.862)
0.090 in. (2.286 mm)	¾ CTS	580 (4.000)
0.090 in. (2.286 mm)	1 CTS	440 (3.034)
0.090 in. (2.286 mm)	1¼ CTS	350 (2.414)
SCH 40	½ IPS	750 (5.172)
SCH 40	¾ IPS	600 (4.138)
SCH 40	1 IPS	570 (3.931)
SCH 40	1 ¼ IPS	460 (3.172)
SCH 40	1 ½ IPS	420 (2.897)
SCH 40	2 IPS	350 (2.414)
SCH 40	3 IPS	330 (2.276)
SCH 40	4 IPS	280 (1.931)
SCH 40	6 IPS	220 (1.517)
SCH 40	8 IPS	200 (1.379)
SCH 40	10 IPS	180 (1.241)
SCH 40	12 IPS	170 (1.172)
SCH 40	16 IPS	165 (1.138)
SCH 40	20 IPS	155 (1.069)

[A] Fiber stress of 2520 psi (17.4 MPa) for PE2406 and PE3408.
[B] Refers to IPS and ISO diameters shown in Table 2 and Table 3.

When the fittings are to be installed under a system specification (such as Specification D 2513 for gas), the minimum requirements of that specification must be satisfied.

10. Test Methods

10.1 *General*—The test methods in this specification cover fittings to be used with pipe and tubing for gas, water, and other engineered piping systems. Test methods that are applicable from other specifications will be referenced in the paragraph pertaining to the particular test. Certain special test methods applicable to this specification only are explained in the appropriate paragraph.

10.2 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73.4 ± 3.6°F (23 ± 2°C) for not less than 6 h in air, or 1 h in water, for those tests where conditioning is required and in all cases of disagreement. Newly molded fittings shall be conditioned 40 h prior to test.

10.3 *Test Conditions*—Conduct the tests at the standard laboratory temperature of 73.4 ± 3.6°F (23 ± 2°C) unless otherwise specified.

10.4 *Dimensions and Tolerances:*

10.4.1 *Outside Diameter*—Measure the outside diameter of the fittings at the area of fusion in accordance with the Wall Thickness section of Method D 2122 by use of a circumferential tape readable to the nearest 0.001 in. (0.02 mm).

10.4.2 *Inside Diameter (CTS Fittings Only)*—Use a stepped plug gage to determine the inside diameter of the CTS end of the fitting. The plug gage shall be of the go/no go type and shall have ½-in. (12.7-mm) land lengths cut to the minimum inside diameter and maximum inside diameter. A fitting is unacceptable (no go) if it fits snugly on the minimum inside diameter land of the gage or if it fits loosely on the maximum diameter land of the gage.

10.4.3 *Wall Thickness*—Make a series of measurements using a cylindrical anvil tubular micrometer or other accurate device at closely spaced intervals to ensure that minimum and maximum wall thicknesses to the nearest 0.001 in. (0.02 mm) have been determined. Make a minimum of six measurements at each cross section.

10.5 *Pressure Testing*:

10.5.1 *Preparation of Specimens for Pressure Testing*—Prepare test specimens in such a manner that each, whether individual fittings or groups of fittings, is a system incorporating at least one length of pipe or tubing. Fuse all fitting outlets with the appropriate size pipe or tubing. At least one piece of pipe or tubing in the system shall have a minimum length equal to five pipe diameters.

10.5.2 *Sustained Pressure Test*:

10.5.2.1 Select the test temperature and pressures from one of the options offered in Table 8.

10.5.2.2 Select six test specimens at random and condition at the selected option test temperature. Test the fittings specimens with water, in accordance with Test Method D 1598 at the selected option of temperature, stress, and hours of testing.

NOTE 2—Other test mediums and test conditions than offered in Table 8 may be used as agreed upon between the manufacturer and the purchaser.

TABLE 8 Sustained Pressure Test Options for Common Fitting Sizes

Wall Thickness DR or Schedule	Nominal Diameter	Option 1[A,B] At 73.4°F (23°C) for 1000 h PE2406 psig, MPa	PE3408 Material Only psig,MPa	Option 2[C,B] At 176°F (80.0°C) for 1000 h PE2406 PE3408 psig, MPa	Option 3[D,B] At 176°F (80.0°C) for 170 h PE2406 PE3408 psig, MPa
DR 7	[E]	440 (3.036)	535 (3.692)	195 (1.346)	225 (1.553)
SDR 9	[E]	330 (2.277)	400 (2.760)	145 (1.001)	170 (1.173)
DR 9.3	[E]	320 (2.208)	385 (2.657)	140 (0.966)	160 (1.104)
SDR 11	[E]	265 (1.829)	320 (2.208)	115 (0.794)	135 (0.932)
DR 11.5	[E]	250 (1.725)	305 (2.105)	110 (0.759)	130 (0.897)
DR 15.5	[E]	180 (1.242)	220 (1.518)	80 (0.552)	90 (0.621)
SDR 17	[E]	165 (1.139)	200 (1.380)	75 (0.504)	85 (0.587)
SDR 21	[E]	130 (0.897)	160 (1.104)	60 (0.414)	65 (0.449)
DR 26	[E]	105 (0.728)	130 (0.0883)	45 (0.320)	55 (0.370)
DR 32.5	[E]	85 (0.587)	101 (0.690)	35 (0.242)	40 (0.276)
0.062	½ CTS	290 (2.001)	350 (2.415)	130 (0.897)	150 (1.035)
0.062	¾ CTS	200 (1.380)	245 (1.691)	90 (0.621)	100 (0.690)
0.062	1 CTS	155 (1.070)	185 (1.277)	70 (0.483)	80 (0.552)
0.090	½ CTS	445 (3.071)	540 (3.726)	195 (1.346)	225 (1.553)
0.090	¾ CTS	305 (2.105)	365 (2.519)	135 (0.932)	155 (1.070)
0.090	1 CTS	230 (1.587)	280 (1.932)	100 (0.690)	115 (0.794)
0.090	1 ¼ CTS	185 (1.277)	225 (1.553)	80 (0.552)	95 (0.656)
SCH 40	½ IPS	395 (2.726)	475 (3.278)	175 (1.208)	200 (1.380)
SCH 40	¾ IPS	320 (2.208)	385 (2.657)	140 (0.966)	160 (1.104)
SCH 40	1 IPS	295 (2.036)	360 (2.484)	130 (0.897)	150 (1.035)
SCH 40	1 ¼ IPS	245 (1.691)	295 (2.036)	105 (0.725)	125 (0.863)
SCH 40	1 ½ IPS	220 (1.518)	265 (1.829)	95 (0.656)	110 (0.759)
SCH 40	2 IPS	185 (1.277)	220 (1.518)	80 (0.552)	95 (0.656)
SCH 40	3 IPS	175 (1.208)	210 (1.449)	75 (0.518)	90 (0.621)
SCH 40	4 IPS	145 (1.001)	180 (1.242)	65 (0.449)	75 (0.518)
SCH 40	6 IPS	115 (0.794)	140 (0.966)	50 (0.345)	60 (0.414)
SCH 40	8 IPS	100 (0.690)	125 (0.863)	45 (0.311)	50 (0.345)
SCH 40	10 IPS	95 (0.656)	110 (0.759)	40 (0.276)	45 (0.311)
SCH 40	12 IPS	85 (0.587)	105 (0.725)	40 (0.276)	45 (0.311)
SCH 40	16 IPS	85 (0.587)	105 (0.725)	35 (0.242)	45 (0.311)
SCH 40	20 IPS	80 (0.552)	100 (0.690)	35 (0.242)	40 (0.276)

[A] Test at 73.4° fiber stress of 1320 psi (9 MPa) for PE2406. Fiber stress of 1600 psi (11.02 MPa) for PE3408.
[B] 170 h elevated temperature test fiber stress of 670 psi (4.6 MPa) all materials.
[C] All psig values were rounded to nearest 5 psig.
[D] 1000 h elevated temperature test fiber stress of 580 psi (4.0 MPa) all materials.
[E] Refers to IPS and ISO diameters shown in Table 2 and Table 3.

10.5.2.3 Failure of two of the six specimens tested shall constitute failure of the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens in retest shall constitute failure of the test.

10.5.3 *Minimum Hydrostatic Burst Pressure for Fittings* ½ to 12 in. and 90 to 315 mm, Nominal Diameter—The test equipment, procedures, and failure definitions shall be as specified in Test Method D 1599. The hydrostatic pressure shall be increased at a uniform rate such that the specimen fails between 60 and 70 s from start of test. Minimum failure pressures are shown in Table 7.

10.5.4 *Minimum Hydrostatic Pressure for Fittings 14 to 48 in. and 355 to 1600 mm, Nominal Diameter*—The test equipment and procedures shall be as specified in Test Method D 1599. The hydrostatic pressure shall be increased at a uniform rate such that the test pressure is reached within 60 to 70 s from the start of the test. No failure should occur in the sample during the test period.

11. Product Marking

11.1 Fittings shall be marked with the following:

11.1.1 This designation: "ASTM D 3261,''

11.1.2 Manufacturer's name or trademark,

11.1.3 Material designations (such as PE2406 or PE3408),

11.1.4 Date of manufacture or manufacturing code,

11.1.5 Size.

11.2 Where the physical size of the fitting does not allow complete marking, marking may be omitted in the following sequence: size, date of manufacture, material designation, manufacturer's name or trademark.

11.3 Where recessed marking is used, take care not to reduce the wall thickness below the minimum specified.

12. Quality Assurance

12.1 When the product is marked with this designation, D 3261, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

13. Keywords

13.1 butt fusion fittings; fittings; polyethylene fittings; polyethylene pipe; polyethylene tubing

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT / MILITARY PROCUREMENT

These requirements apply *only* to federal / military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a Regulatory Authority or ser calls for the product to be used to convey or to be in contact with potable water.

S3. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 or the health effects portion of NSF Standard 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

Designation: D 3350–06

Standard Specification for
Polyethylene Plastics Pipe and Fittings Materials[1]

This standard is issued under the fixed designation D 3350; 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.

1. Scope[*]

1.1 This specification covers the identification of polyethylene plastic pipe and fittings materials in accordance with a cell classification system. It is not the function of this specification to provide specific engineering data for design purposes, to specify manufacturing tolerances, or to determine suitability for use for a specific application.

1.2 Polyethylene plastic materials, being thermoplastic, are reprocessable and recyclable (Note 2). This specification allows for the use of those polyethylene materials, provided that all specific requirements of this specification are met.

NOTE 1—The notes in this specification are for information only and shall not be considered part of this specification.

NOTE 2—See Guide D 5033 for information and definitions related to recycled plastics.

1.3 The values stated in SI units are to be regarded as standard.

1.4 *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.*

NOTE 3—There is no similar or equivalent ISO standard.

1.5 For information regarding molding and extrusion materials see Specification D 4976. For information regarding wire and cable materials see Specification D 1248.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D 618 Practice for Conditioning Plastics for Testing
D 638 Test Method for Tensile Properties of Plastics
D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D 883 Terminology Relating to Plastics
D 1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black Content in Olefin Plastics

[1]This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials .

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[*]A Summary of Changes section appears at the end of this standard.

[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.

D 1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics
D 1898 Practice for Sampling of Plastics[3]
D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D 2839 Practice for Use of a Melt Index Strand for Determining Density of Polyethylene
D 3892 Practice for Packaging/Packing of Plastics
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
D 4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D 4883 Test Method for Density of Polyethylene by the Ultrasound Technique
D 4976 Specification for Polyethylene Plastics Molding and Extrusion Materials
D 5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics
F 1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins

2.2 *ISO Standard:*

ISO 12162 Thermoplastic Materials for Pipes and Fittings for Pressure Applications—Classification and Designation—Overall Service (Design) Coefficient

3. Terminology

3.1 *Definitions*—Terms as described in Terminology D 883 shall apply in this specification.

3.1.1 *polyethylene plastics*—as defined by this specification, plastics or resins prepared by the polymerization of no less than 85 % ethylene and no less than 95 % of total olefins with additional compounding ingredients.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *materials*—polyethylene (PE) resins with the added compounding ingredients.

3.2.2 *PE compounds*—has the same meaning as PE plastics materials, compounds, and plastics.

3.3 Historical usage and user group conventions have resulted in inconsistent terminology used to categorize and describe polyethylene resins and compounds. The following terminology is in use in ASTM specifications pertaining to polyethylene:

3.3.1 *Specification D 1248*:

3.3.1.1 Type (0, I, II, III, IV) = density ranges (same, respectively, as Class in Specification D 4976).

3.3.1.2 Class (A, B, C, D) = composition and use.

3.3.1.3 Category (1, 2, 3, 4, 5) = melt index ranges (same as Grade in Specification D 4976).

3.3.1.4 Grade (E, J, D, or W followed by one or two digits) = specific requirements from tables.

3.3.2 *Specification D 3350* :

3.3.2.1 Type (I, II, III) = density ranges (same as Types I, II, and III in Specification D 1248 and Classes 1, 2, and 3 in Specification D 4976).

3.3.2.2 Class = a line callout system consisting of "PE" followed by six cell numbers from Table 1 plus a letter (A, B, C, D, E) denoting color and UV stabilizer.

3.3.2.3 Grade = simplified line callout system using "PE" followed by density and slow crack growth cell numbers from Table 1.

3.3.3 *Specification D 4976*:

3.3.3.1 Group (1, 2) = branched or linear polyethylene.

3.3.3.2 Class (0, 1, 2, 3, 4) = density ranges (same, respectively, as Type in Specification D 1248).

3.3.3.3 Grade (1, 2, 3, 4, 5) = melt index ranges (same as Category in Specification D 1248).

4. Classification

4.1 Polyethylene plastic pipe and fittings compounds are classified in accordance with density, melt index, flexural modulus, tensile strength at yield, slow crack growth resistance, and hydrostatic strength classification in Table 1.

NOTE 4—It has been a long-standing practice to use the following terms in describing polyethylene plastics:

[3] Withdrawn.

Type I (0.910 to 0.925) = Low Density
Type II (0.926 to 0.940) = Medium Density
Type III (0.941 to 0.965) = High Density

NOTE 5—The manner in which materials are identified in the cell classification is illustrated for Class PE233424B as follows (refer also to Table 1 and 6.2):

Class
2 3 3 4 2 4 B

Density (0.926–0.940 g/cm³) — 2
Melt index (<0.4–0.15) — 3
Flexural modulus (276–<758 MPa
(40 000–<110 000 psi)) — 3
Tensile strength at yield (21–<24 MPa
(3000–<3500 psi)) — 4
Slow Crack Growth Resistance — 2
I. ESCR D 1693
Condition B, 24 h, 50 % max failure
II. PENT F 1473
Average 1 h failure
Hydrostatic design basis at 23°C — 4
(11.03 MPa (1600 psi))
Color and UV stabilizer (colored) — B

4.2 Materials used in polyethylene plastic pipe and fittings shall use a cell-type format for the identification, close characterization, and specification of material properties. The information from the format is to be used alone or in combination.

NOTE 6—This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted. Additionally, the appropriate ASTM standard specification should be reviewed to assure materials utilized will meet all the material and piping requirements as specified in the standard.

4.3 *Grade*—A code for polyethylene pipe and fittings materials that consists of the two letter abbreviation for polyethylene (PE) followed by two numbers that designate the density cell (Property 1) and the slow crack growth resistance cell (Property 5), as defined by either Test Method F 1473 or Test Method D 1693, of the thermoplastic, as specified in Table 1. For the requirements of Property 5 (slow crack growth resistance), consult the materials section of the appropriate ASTM standard specification for the end-use application.

NOTE 7—Grade designations were adapted from Specification D 1248 - 84 prior to the removal of pipe material from D 1248 - 84. Former Specification D 1248 - 84 grades for PE pipe materials were P14, P23, P24, P33, and P34. Equivalent Specification D 3350 grade designations for these materials are PE11, PE20, PE23, PE30, and PE33, respectively.

5. Materials and Manufacture

5.1 The molding and extrusion material shall be polyethylene plastic in the form of powder, granules, or pellets.

5.2 The molding and extrusion materials shall be as uniform in composition and size and as free of contamination as is achieved by good manufacturing practice. If necessary, the level of contamination may be agreed upon between the manufacturer and the purchaser.

5.3 When specified, the color and translucence of molded or extruded pieces formed, under the conditions specified by the manufacturer of the materials, shall be comparable within commercial match tolerances to the color and translucence of standard samples supplied in advance by the manufacturer of the material.

6. Physical Properties

6.1 *Cell Classification*—Test values for specimens of the PE material prepared as specified in Section 9 and tested in accordance with Section 10 shall conform to the requirements given in Table 1. A typical property value for a PE material is to be the average value from testing numerous lots or batches and determines the cell number. When, due to manufacturing tolerances and testing bias, individual lot or batch values fall into the adjoining cell, the individual value shall not be considered acceptable unless the user, or both the user and the producer, determine that the individual lot or batch is suitable for its intended purpose.

6.2 *Color and Ultraviolet (UV) Stabilizer*—The color and UV stabilization shall be indicated at the end of the cell classification by means of a letter designation in accordance with the following code:

Code Letter	Color and UV Stabilizer
A	Natural
B	Colored
C	Black with 2 % minimum carbon black
D	Natural with UV stabilizer
E	Colored with UV stabilizer

6.3 *Thermal Stability*—The PE material shall contain sufficient antioxidant so that the minimum induction temperature shall be 220°C when tested in accordance with 10.1.9.

6.4 *Brittleness Temperature*—The brittleness temperature shall not be warmer than −60°C when tested in accordance with Test Method D 746.

6.5 *Density*—The density used to classify the material shall be the density of the PE base resin (uncolored PE) determined in accordance with 10.1.3. When the average density of any lot or shipment falls within ±0.002 g/cm^3 of the nominal value, it shall be considered as conforming to the nominal value and to all classifications based on the nominal value.

6.5.1 For black compounds, containing carbon black, determine the density, *Dp*, and calculate the resin density, *Dr*, as follows:

$$Dr = Dp - 0.0044C$$

where:

C = weight percent of carbon black.

6.5.2 For colored compounds, the nominal density of the base resin shall be provided by the manufacturer, on request.

6.6 *Tensile Strength at Yield*—The tensile strength at yield used to classify the material shall be the tensile strength at yield of the PE resin determined in accordance with 10.1.6. When the average tensile strength at yield of any lot or shipment falls within ±3.45 MPa [±500 psi] of the nominal value, it shall be considered as conforming to the nominal value and to all classifications based on the nominal value.

6.7 *Elongation at Break*—As tested in accordance with 10.1.6, all pressure rated materials shall have a minimum extension at break of 500 % as determined by grip separation.

7. Sampling

7.1 A batch or lot shall be considered as a unit of manufacture and shall consist of one production run or as a blend of two or more production runs of material.

7.2 Unless otherwise agreed upon between the manufacturer and the purchaser, the material shall be sampled in accordance with the procedure described in Sections 9 through 12 of Practice D 1898. Adequate statistical sampling prior to packaging shall be considered an acceptable alternative.

NOTE 8—A sample taken from finished product may not necessarily represent the original batch or lot.

8. Number of Tests

8.1 The requirements identified by the material designation and otherwise specified in the purchase order shall be verified by tests made in accordance with 11.1. For routine inspection, only those tests necessary to identify the material to the satisfaction of the purchaser shall be required. One sample shall be sufficient for testing each batch or lot provided that the average values for all of the tests made on that batch or lot comply with the specified requirements.

9. Specimen Preparation

9.1 Unless otherwise specified in Section 10, the test specimens shall be molded in accordance with Procedure C of Annex A1 of Practice D 4703.

9.2 When pipe or fitting test specimens are required, they shall be extruded or molded in accordance with the specifications of the material manufacturer.

10. Test Methods

10.1 The properties enumerated in this specification shall be determined in accordance with the following test methods:

10.1.1 *Conditioning*— Unless otherwise specified in the test methods or in this specification, for those tests where conditioning is required, condition the molded test specimens in accordance with Procedure A of Practice D 618.

10.1.2 *Test Conditions*— Unless otherwise specified in the test methods or in this specification, conduct tests at the standard laboratory temperature of 23 ± 2°C [73.4 ± 3.6°F].

10.1.3 *Density*—Test Method D 1505 or alternative methods referenced in 2.1 (see D 792, D 2839, and D 4883) providing equivalent accuracy. Make duplicate determinations using two separate portions of the same molding or from two moldings. The molded specimen thickness portions shall be 1.9 ± 0.2 mm [0.075 ± 0.008 in.]. Calculate the average value.

10.1.4 *Melt Index*—Test Method D 1238, using Condition 190/2.16. Make duplicate determinations on the material in the form of powder, granules, or pellets, and calculate the average; no conditioning is required.

10.1.4.1 Classify materials having a melt index less than 0.15 (Cell 4) as Cell 5 only if they have a flow rate not greater than 4.0 g/10 min when tested in accordance with Test Method D 1238, Condition 190/21.6.

NOTE 9—Flow rate is the general term used for all results obtained with Test Method D 1238. Although the flow rate of polyethylene plastics may be measured under any of the conditions listed for it under 7.2 of Test Method D 1238, only measurements made at Condition 190/2.16 may be identified as "Melt Index."

10.1.5 *Flexural Modulus*— Test Methods D 790, using Method 1, Procedure B, and a 50-mm [2-in.] test span. Test five specimens, each 3.2 by 12.7 mm [1/8 by 1/2 in.] flatwise at a crosshead speed of 12.7 mm/min [0.5 in./min] and the average value of the secant modulus calculated at 2 % strain in the outer fibers.

10.1.5.1 The deflection of the test specimen corresponding to 2 % strain (0.02 mm/mm or in./in.) is calculated as follows:

$$D = rL^2/6d$$

where:

D	=	deflection of the center of the beam test specimen at 2 % strain, in.,
r	=	strain in the outer fibers = 0.02 mm/mm [0.02 in./in.],
L	=	test span = 50 mm [2 in.], and
d	=	specimen depth = 3.2 mm [1/8 in.].

10.1.5.2 The stress corresponding to 2 % strain is calculated as follows:

$$S = 3\,PL/2\,bd^2$$

where:

S	=	stress in the outer fiber at 2 % strain,
P	=	load corresponding to 2 % strain, N [lbf],
L	=	test span = 50 mm [2 in.],
d	=	specimen depth = 3.2 mm [1/8 in.], and
b	=	specimen width = 12.7 mm [1/2 in.].

The secant modulus at 2 % strain is the ratio of stress to strain or $S/0.02$.

10.1.6 *Tensile Strength at Yield*—The tensile strength at yield shall be determined in accordance with Test Method D 638 except that rate of grip separation shall be 500 mm/min [20 in./min for materials in the density range from 0.910 to 0.925 g/cm^3] and 50 mm/min [2 in./min for all others]. Specimens shall conform to the dimensions given for Type IV in Test Method D 638 with a thickness of 1.9 ± 0.2 mm [0.075 ± 0.008 in.]. Specimen shall be either die cut or machined.

10.1.7 *Slow Crack Growth Resistance* —One method shall be used to classify this material property.

10.1.7.1 *Slow Crack Growth Resistance* —The material's resistance shall meet the minimum requirement shown for the appropriate cell classification when tested in accordance with Test Method D 1693.

10.1.7.2 *Slow Crack Growth Resistance* —The average failure time from two test specimens shall meet the minimum requirement shown for the appropriate cell classification when tested in accordance with Test Method F 1473. Test at least four specimens in case of a dispute.

10.1.8 *Hydrostatic Strength Classification*—One method shall be used to classify this material property.

10.1.8.1 *Hydrostatic Design Basis*—Determine the hydrostatic design basis in accordance with Test Method D 2837, on pipe extruded from three different lots of material. Subject specimens from one lot for at least 10 000 h. Terminate the tests on the two additional lots after 2000 h. The results from each of the three lots shall be within the same or next higher cell limits.

NOTE 10—For pressure application at elevated temperatures, the hydrostatic design basis should be determined at that temperature in accordance with Test Method D 2837. The 100 000-h intercept should be categorized in accordance with Table 1 of Test Method D 2837.

10.1.8.2 *Minimum Required Strength*—Determine the minimum required strength in accordance with ISO 12162.

10.1.9 *Thermal Stability*—Test specimens taken from pipe or fittings made from the virgin material with a differential scanning calorimeter (DSC).[4] The directions of the instrument manufacturer regarding calibration and operation shall be followed except when in conflict with other parts of this section.

NOTE 11—This test requires accurate temperature and atmosphere control on the DSC specimen compartment. The DSC manufacturers offer choices in cell configuration and temperature control parameters that may affect this required control. For example, in some power compensation DSCs, use of the two-hole platinum specimen holder lids with a special “flow-through” swing-away block cover is required. Therefore, the user may wish to consult equipment-specific literature and with the equipment manufacturer to optimize the operation of individual DSCs for this test.

10.1.9.1 *Specimens*—Press small pieces of the pipe into films 0.127 ± 0.013 mm [0.0050 ± 0.0005 in.] thick. Cut at least three disks 6.35 ± 0.13 mm [0.250 ± 0.005 in.] in diameter from the film.

10.1.9.2 *Procedure*—Place the disk of film in a small aluminum cup used in the DSC in a stretched condition, as shown in Fig. 1(*a*). Place a small piece of indium (melting point 156.6°C) or anisic acid (melting point 183.0°C) for a temperature reference standard contained in a similar cup (see Fig. 1(*b*)) in the reference position. Use an oxidized copper reference disk for black, filled, or dark brown test specimens and an aluminum disk for natural or light pigmented polymers. Place the specimen and reference standard cups in the instrument which is preset at approximately 150°C. The bottoms of the cups shall be pressed and rubbed securely against the flat surface so as to ensure that thermal contact is made. Allow 5 min for the cups to reach thermal equilibrium. Begin the programmed heating at approximately 150°C at a heating rate of 10.0°C/min in static air. Test at least three film specimens from each sample and use the average value for the induction temperature.

NOTE 12—Since the indium standard may change with use, it should not be used more than 30 times without confirming that no significant change in melting point has occurred. This check can be made by comparison with a fresh piece of indium.

[4] Instruments are available from TA Instruments, Perkin-Elmer, and others.

10.1.9.3 *Results*—The temperature change (ΔT) or heat absorption rate (J/s) in the specimen plotted against temperature shall produce a line with a clear rise in slope. The induction temperature (degradation onset) is the intersection of the extended base line and a line tangent to the leading slope of the exothermic decomposition peak (see Fig. 2).

10.1.10 *Carbon Black Content*—Test Method D 1603 or Test Method D 4218 shall be used. Make duplicate determinations from a sample of the material in the form of powder, granules, or pellets.

11. Inspection

11.1 Inspection of the material shall be made as agreed upon between the purchaser and the manufacturer as part of the purchase contract.

12. Retest and Rejection

12.1 If any failure occurs, and when specified by the manufacturer, the material shall be retested to establish conformity in accordance with the agreement between the purchaser and the manufacturer.

13. Packaging and Marking

13.1 *Packaging*—The material shall be packaged in standard commercial containers, so constructed as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery, unless otherwise specified in the contract or order.

13.2 *Marking*—Unless otherwise agreed upon between the seller and the purchaser, shipping containers shall be marked with the name of the material, identification in accordance with this specification, the lot or batch number and quantity contained therein, as defined by the contract or order under which shipment is made, and the name of the manufacturer.

13.3 All packing, packaging, and marking provisions of Practice D 3892 shall apply to this specification.

14. Keywords

14.1 cell classification system; pipe and fittings material; polyethylene; recycled

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue, D 3350 - 05, that may impact the use of this standard. (November 15, 2006)

(1) Added D 2839, D 4218, and D 4883 to 2.1.

(2) Revised 10.1.3 and 10.1.10.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue, D 3350 - 04, that may impact the use of this standard. (September 15, 2005)

(1) Modified PENT cell classes in Table 1.

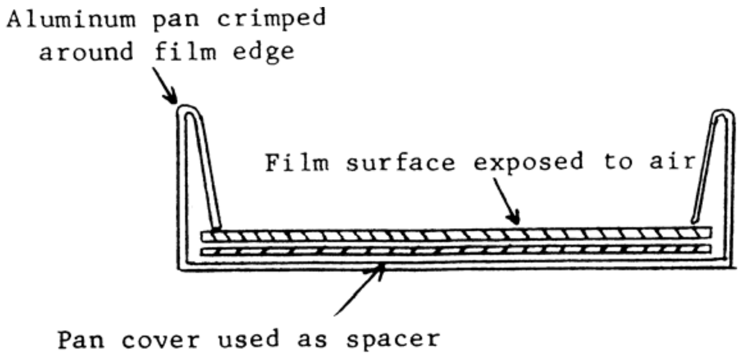
(2) Removed sentence from 4.3. Thermoplastic material designation codes such as PE 2406 or PE 3408 are more commonly used in pipe application standards than grade designations. As represented in Specification D 3350-04, a PE 2406 or PE 3408 material may have a slow crack growth cell of 4 or 6. Modification of the PENT cells will result in a thermoplastic material designation code upgrade as represented by the slow crack growth properties of the material. For example, a traditional PE 3408 material with >100 hours PENT will be designated as PE 3608 and a traditional PE 3408 material with >500 hours PENT will be designated as PE 3708.

TABLE 1 Primary Properties—Cell Classification Limits

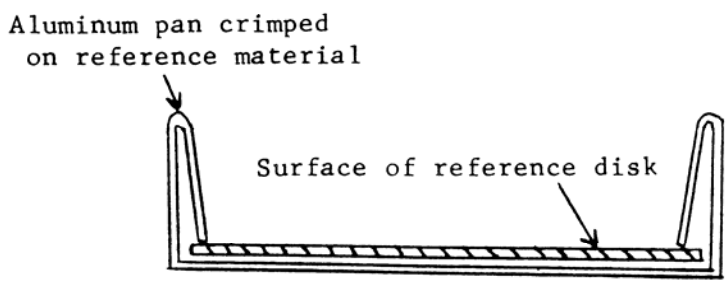
Property	Test Method	0	1	2	3	4	5	6	7	8
1. Density, g/cm^3	D 1505	Unspecified	0.925 or lower	>0.925-0.940	>0.940-0.947	>0.947-0.955	>0.955	. . .	Specify Value	
2. Melt index	D 1238	Unspecified	>1.0	1.0 to 0.4	<0.4 to 0.15	<0.15	[A]		Specify Value	
3. Flexural modulus, MPa [psi]	D 790	Unspecified	<138 [<20 000]	138-<276 [20 000 to <40 000]	276-<552 [40 000 to 80 000]	552-<758 [80 000 to 110 000]	758-<1103 [110 000 to <160 000]	>1103 [>160 000]	Specify Value	
4. Tensile strength at yield, MPa [psi]	D 638	Unspecified	<15 [<2200]	15-<18 [2200-<2600]	18-<21 [2600-<3000]	21-<24 [3000-<3500]	24-<28 [3500-<4000]	>28 [>4000]	Specify Value	
5. Slow Crack Growth Resistance										
I. ESCR	D 1693	Unspecified								
a. Test condition (100% Igepal.)			A	B	C	C	. . .	. . .	. . .	Specify Value
b. Test duration, h			48	24	192	600				
c. Failure, max, %		Unspecified	50	50	20	20				
II. PENT (hours)	F 1473									
Molded plaque, 80°C, 2.4 MPa		Unspecified	. . .	. . .	. . .	10	30	100	500	Specify Value
Notch depth, F 1473, Table 1		Unspecified								
6. Hydrostatic Strength Classification										
I. Hydrostatic design basis, MPa [psi], (23°C)	D 2837	NPR [B]	5.52 [800]	6.89 [1000]	8.62 [1250]	11.03 [1600]	. . .	. . .		

Property	Test Method	0	1	2	3	4	5	6	7	8
II. Minimum required strength, MPa [psi], (20°C)	ISO 12162	. . .	. . .	. . .	. . .	. . .	8 [1160]	10 [1450]		

[A] Refer to 10.1.4.1.
[B] NPR = Not Pressure Rated.



(*a*) Specimen in pan.



(*b*) *Reference*—Temperature standard shall be placed under reference disk in reference pan or alternatively under pan cover (spacer).

FIG. 1 Mounting Film Specimen in Cup

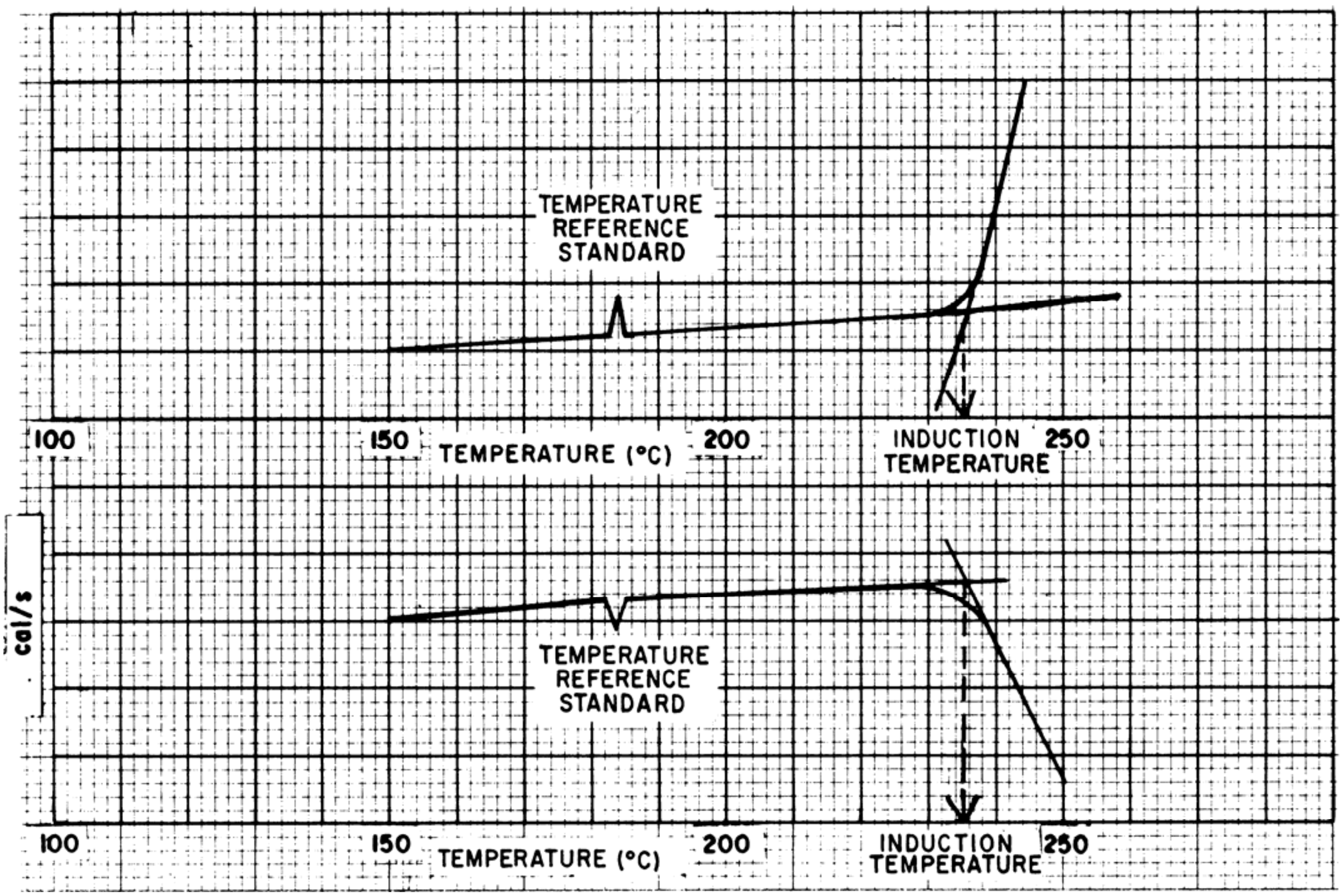


FIG. 2 Typical DSC Plots

Designation: F 714 – 03

An American National Standard

Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter[1]

This standard is issued under the fixed designation F 714; 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.

1. Scope

1.1 This specification covers polyethylene (PE) pipe made in dimensions based on outside diameters of 90 mm (3.500 in.) and larger.

1.2 Three standard outside diameter sizing systems are detailed: one known as the ISO metric system, one known as the IPS system, and the other known as the DIPS system. See 5.2.5 for guidelines for special sizes.

1.3 The piping is intended for new construction and insertion renewal of old piping systems used for the transport of water, municipal sewage, domestic sewage, industrial process liquids, effluents, slurries, etc., in both pressure and nonpressure systems.

NOTE 1—The user must consult the manufacturer to ensure that any damage of the polyethylene pipe caused by the material being transported will not affect the service life beyond limits acceptable to the user.

1.4 All pipes produced under this specification are pressure-rated.

1.5 This specification includes criteria for choice of raw material and test methods for evaluation of raw material, together with performance requirements and test methods for determining conformance with the requirements.

1.6 Quality-control measures to be taken by manufacturers, are outlined in the appendix as a nonmandatory part of this specification.

1.7 In referee decisions, the SI units shall be used for metric-sized pipe and inch-pound units for pipe sized in the IPS system (ANSI B36.10) and DIPS system. In all cases, the values given in parentheses are provided for information only.

1.8 The following safety hazards caveat pertains only to the test methods portion, Section 6, 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 Melt Flow Rates of Thermoplastics by Extrusion Plastometer[2]

D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable[2]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[2]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method[3]

D 2321 Practice for Underground Installation of Flexible Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[3]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[3]

D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials[4]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 585 Practice for Insertion of Flexible Polyethylene Pipe Into Existing Sewers[3]

2.2 *ANSI Standard:*

B 36.10 Standard Dimensions of Steel Pipe (IPS)[5]

2.3 *ISO Standards:*

161 Thermoplastic Pipe for the Transport of Fluids - Nominal Outside Diameters and Nominal Pressures[6]

3607 Polyethylene Pipe: Tolerances on Outside Diameters

[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 1981. Last previous edition approved in 2001 as F 714 – 01.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

[6] Available from International Organization for Standardization, Central Secretariat, 1, rue de Varembe, Case Postale 56, CH-1211 Geneve 20, Switzerland/Suisse.

and Wall Thicknesses[6]

4427 Polyethylene Pipes and Fittings for Water Supply Specification[6]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[7]

2.5 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[7]

2.6 *Canadian Standard:*

CGSB 41 GP-25M Pipe, Polyethylene for the Transport of Liquids[8]

2.7 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials[9]

Standard No. 61 for Drinking Water Systems Components—Health Effects[9]

3. Terminology

3.1 *Definitions*—General terms used in this specification are as defined in Terminology F 412.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *relation between dimension ratio, hydrostatic design stress, and hydrostatic pressure:*

$$P = \frac{2S}{(D_O/t)-1}$$

where:

S = hydrostatic design stress, psi (or Pa),
P = pressure rating, psi (or Pa),
D_O = average outside diameter, in. (or mm),
t = minimum wall thickness, in. (or mm), and
D_O/t = dimension ratio.

3.2.2 *relations between hydrostatic design basis and hydrostatic design stress*—the hydrostatic design stress, S, is determined by multiplying the hydrostatic design basis (HDB) by the design factor, n. The design factor, n, has a value less than 1.0.

3.2.2.1 The hydrostatic pressure rating of pipes (see Table 1(a)) described in this specification is based on the use of a (service) design factor (see 2.3) of 0.5 in accordance with the instruction given in Test Method D 2837.

NOTE 2—This factor is valid for water and domestic sewage transported at temperatures up to 23°C when the pipe is installed in accordance with the appropriate standard procedures. Smaller design factors should be applied to systems operating at higher temperatures, or high surge pressures resulting from changing velocity or where pipe is to be used for the transport of industrial effluents known to have some degrading effect on the properties of polyethylene, or where erosion of the pipe wall by the fluid being transported will adversely affect the service life of the system. The actual choice of design factor for a given installation must be reviewed by the designing engineer, taking into account the transportation and on-site handling conditions, the difficulties of site preparation, the contractual specifications for trenching, bedding, haunching, backfilling, and the possibility of deviation from operating at hydrostatic pressures or external load conditions specified for the use of the piping system. A further uncertainty factor should be applied at the designing engineer's discretion where warranted by consideration of these conditions.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[8] Available from Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario, Canada, M 9W 1R3.

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

TABLE 1 Pressure Rating and Pressure Performance Tests[A]

Table 1(a) Standard Pressure Rating (2.2)[B]

HDB		DR41		DR32.5		DR26		DR21		DR17		DR15.5		DR11		DR9.3		DR9		DR7.3	
MPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi
8.6	1250	215	31	275	40	345	50	430	63	540	78	595	86	860	125	1035	150	1075	156	1365	198
10	1450	250	36	315	46	400	58	500	72	625	91	690	100	1000	145	1205	175	1250	181	1585	230
11	1600	275	40	350	50	440	64	550	80	690	100	760	110	1100	160	1325	192	1380	200	1750	254

TABLE 1(b) Short-Term Pressure Test (6.2.1)

HDB and Density	DR41		DR32.5		DR26		DR21		DR17		DR15.5		DR11		DR9.3		DR9		DR7.3	
	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi
All HDB Medium density	860	125	1095	159	1380	200	1725	250	2155	312	2380	345	3450	500	4155	602	4310	625	5475	794
High density	1000	145	1270	184	1600	232	2000	290	2500	363	2760	400	4000	580	4820	699	5000	725	6350	921

TABLE 1(c) Sustained Pressure Test, 1000 h (6.2.2)

HDB		DR41		DR32.5		DR26		DR21		DR17		DR15.5		DR11		DR9.3		DR9		DR7.3[AB]	
MPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi
8.6	1250	445	64	570	83	720	104	895	131	1125	162	1235	179	1790	260	2150	312	2240	325	2840	412
10	1450	520	75	655	96	830	121	1040	150	1300	189	1435	208	2080	302	2510	364	2595	376	3275	478
11	1600	552	80	701	102	883	128	1103	160	1379	200	1580	229	2207	320	2750	399	2870	416	3640	528

[A] Pressures specified for the performance tests are derived as follows:

Table 1(b) Short-Term Pressures:

All HDB, medium-density materials – 2500 psi fiber stress

All HDB, high-density materials – 2900 psi fiber stress

Table 1(c) Sustained pressure for 1000 h is 2.08 × standard pressure rating,Table 1 (a) or maximum of 1600 psi fiber stress.

[B] In some international standards, this rating may be expressed in "bars" (1 bar = 100 kPa). The "bar" is not a recognized unit in U.S. or Canadian Standard Codes of metric (SI) practice.

4. Materials

4.1 *Polyethylene Plastics*, used to make pipe meeting the requirements of this specification are categorized, by testing, for long-term strength and by the analysis of results of this testing to determine the hydrostatic design basis. Three categories of polyethylene plastic compounds having hydrostatic design basis of 1250 psi (8.6 MPa), 1450 psi (10 MPa), or 1600 psi (11 MPa) as categorized in Table 2 shall be used for the manufacture of pipe under this specification.

4.2 *Compound*—The resin compounds used shall meet the general physical requirements listed in Specification D 3350, except that the hydrostatic design basis shall be in accordance with 4.1 and Table 2 of this specification. The polyethylene compounds shall be color and UV stabilizer Code C (black with 2 % minimum carbon black) or Code E (colored with UV stabilizer) as specified in Specification D 3350.

4.2.1 The 80°C sustained pressure performance requirements of 5.3.4 (pipe test category in Table 3) are not currently in PE material Specifications D 1248 or D 3350. 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 3—Committee F-17 has requested that Committee D-20 add the 80°C sustained pressure performance requirements to Specifications D 1248 and D 3350.

NOTE 4—The hydrostatic design basis of 1450 psi (10 MPa) is not included in the cell classifications of Property 6, in Table 1 of Specification D 3350. However, it is an internationally recognized value and is used in the form of a standardized design stress of 725 psi (5 MPa) in many national and international standards outside of the United States, including ISO 4427 and CGSB 41-GP-25M.

4.3 *Rework Material*—Clean polyethylene compound reclaimed from the manufacturer's own pipe production may be reextruded into pipe, either alone or blended with new compound of the same cell classification. Pipe containing the rework material must meet all the material and product requirements of this specification.

4.4 *Cell Classification of Polyethylene Pipe Materials*—Polyethylene materials suitable for use in the manufacture of pipe under this specification shall be classified in accordance with Specification D 3350, and as shown in Table 4, for example, for a polyethylene material having a HDB of 1250 psi (8.6 MPa), the base resin density must have a cell classification of 2 or 3; the melt index cell classification must be 1, 2, or 3, etc.

5. Requirements

5.1 *Workmanship*—The pipe shall be homogeneous throughout and essentially uniform in color, opacity, density, and other properties. The inside and outside surfaces shall be semimatte or glossy in appearance (depending on the type of plastic) and free of chalking, sticky, or tacky material. The surfaces shall be free of excessive bloom, that is, slight bloom is acceptable. The pipe walls shall be free of cracks, holes, blisters, voids, foreign inclusion, or other defects that are visible to the naked eye and that may affect the wall integrity. Holes deliberately placed in perforated pipe are acceptable. Bloom or chalking may develop in pipe exposed to direct rays of the sun (ultraviolet radiant energy) for extended periods and, consequently, these requirements do not apply to pipe after extended exposure to direct rays of the sun.

TABLE 2 Hydrostatic Design Basis

Minimum Calculated LTHS Value[A]		Hydrostatic Design Basis	
psi	MPa	psi	MPa
1200	(8.3)	1250	(8.6)
1390	(9.6)	1450	(10.0)
1530	(10.6)	1600	(11.0)

[A] 96 % of hydrostatic design basis.

5.2 *Dimensions and Tolerances:*

5.2.1 *Outside Diameters*—These shall be in accordance with Table 5 (SI units), Table 6 (inch-pound units) or Table 7 (inch-pound units) when measured in accordance with Test Method D 2122 at any point not closer than 300 mm (11.8 in.) to the cut end of a length of pipe. Conditioning to standard temperature but not to standard humidity is required.

5.2.2 *Wall Thicknesses*—The minimum thicknesses shall be in accordance with Table 8 (inches), Table 9 (inches), or Table 10 (inches) when measured in accordance with Test Method D 2122. Conditioning to standard temperature but not to standard humidity is required.

5.2.3 *Eccentricity*—The wall thickness variability as measured and calculated in accordance with Test Method D 2122 in any diametrical cross section of the pipe shall not exceed 12 %.

5.2.4 *Toe-In*—When measured in accordance with 5.2.1, the outside diameter at the cut end of the pipe shall not be more than 1.5% smaller than the undistorted outside diameter. Measurement of the undistorted outside diameter shall be made no closer than 1.5 pipe diameters or 11.8 in. (300 mm), whichever distance is less, from the cut end of the pipe. Undistorted outside diameter shall meet specifications in Table 5, Table 6, or Table 7.

5.2.5 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable for engineered applications when mutually agreed upon by the customer and the manufacturer, if the pipe is manufactured from plastic compounds meeting the material requirements of this specification, and the strength and design requirements are calculated on the same basis as those used in this specification. For diameters not shown in Table 5, Table 6, or Table 7, the tolerance shall be the same percentage as that shown in the corresponding tables for the next smaller listed size. Minimum wall thicknesses for DRs not shown in Table 8,Table 9, or Table 10 shall comply with 3.2.2.1 and the tolerance shall comply with 5.2.3.

5.3 *Pressure Test Performance*—All grades of PE pipe shall meet the requirements of 5.3.1. Pipe made from PE materials designated PE2406, PE3406 or PE3408 shall meet the requirement of 5.3.2. Pipe made from other PE materials shall meet the requirements of 5.3.3 and 5.3.4.

NOTE 5—The requirements of 5.3.1 and 5.3.3 are for laboratory proof-testing only and should not be interpreted as applicable to in situ testing for acceptance of installed systems. See appropriate installation standards or manufacturer's recommendations for field testing procedure.

TABLE 3 176°F (80°C) Sustained Pressure Requirements for Water Pipe[A]

Pipe Test Category[B]	Base Resin Melt Index, D 1238 (g/10 min)	Base Resin Density,[C] D 1505 (g/cm^3)	Minimum Average Hours to Failure		
			S = 725 psi (5 MPa)	S = 580 psi (4 MPa)	S = 435 psi (3 MPa)
C1	<0.05	0.941–0.948	100	200	—
C2	<0.05	0.935–0.940	100	200	—
C3	0.05–0.25	0.941–0.948	60	150	—
C4	0.05–0.25	0.935–0.940	60	150	—
C5	>0.25	0.941–0.948	45	100	—
C6	>0.25	0.935–0.940	45	100	—
C7	>0.50	0.926–0.940	—	80	150

[A] For outside diameter controlled pipe, calculate internal pressure in accordance with the following formula:

$$P = \frac{2S}{\frac{D_o}{t} - 1}$$

where:
P = pressure, psig (MPa),
S = hoop stress, psi (MPa),
D_o = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

[B] Supplier to determine pipe test category appropriate for his product.
[C] Pipe categories for water pipe with resin density below 0.926 g/cm^3 or above 0.948 g/cm^3 will be added to this table when the data are available.

TABLE 4 Classification of Polyethylene Pipe Materials

For HDB of	1250 psi (8.6 MPa)	1450 psi (10 MPa)	1600 psi (11 MPa)
Physical Properties and Cell Classification Limits are:			
Density (base resin)	2 or 3	2 or 3	2 or 3
Melt/Index	1, 2, or 3	3, 4, or 5	3, 4, or 5
Flexural modulus	4 or 5	3, 4, or 5	4 or 5
Tensile strength	2 or 3	3, 4, or 5	3, 4, or 5
ESCR	1, 2, or 3	3	3
Color and UV stabilizer code	C or E	C or E	C or E

TABLE 5 Outside Diameters and Tolerances

ISO Sizing System (ISO 161/1)			
Nominal Pipe Size	Equivalent	Outside Diameter, D_o, mm	
mm	in.	min	max[A]
90	3.543	90	90.8
110	4.331	110	111.0
160	6.299	160	161.4
200	7.874	200	201.8
250	9.843	250	252.3
280	11.024	280	282.5
315	12.402	315	317.8
355	13.976	355	358.2
400	15.748	400	403.6
450	17.717	450	454.1
500	19.685	500	504.5
560	22.047	560	565.0
630	24.803	630	635.7
710	27.953	710	716.4
800	31.496	800	807.2
900	35.433	900	908.1
1000	39.370	1000	1009.0
1200	47.244	1200	1210.8
1400	55.118	1400	1412.6
1600	62.992	1600	1614.4

[A] As specified in ISO 3607.

TABLE 6 Outside Diameters and Tolerances IPS Sizing System (ANSI B36.10)

Nominal Pipe Size, in.	Equivalent, mm	Actual Outside Diameters, in.	
		Average	Tolerance ± in.
3	88.9	3.500	0.016
4	114.3	4.500	0.020
5[A]	136.5	5.375	0.025
5	141.3	5.563	0.025
6	168.3	6.625	0.030
7[A]	181.0	7.125	0.034
8	219.1	8.625	0.039
10	273.1	10.750	0.048
12	323.8	12.750	0.057
13[A]	339.7	13.375	0.060
14	355.6	14.000	0.063
16	406.4	16.000	0.072
18	457.2	18.000	0.081
20	508.0	20.000	0.090
21.5[A]	546.1	21.500	0.097
22	558.8	22.000	0.099
24	609.6	24.000	0.108
26	660.4	26.000	0.117
28	711.2	28.000	0.126
30	762.0	30.000	0.135
32	812.8	32.000	0.144
34	863.6	34.000	0.153
36	914.4	36.000	0.162
42	1066.8	42.000	0.189
48	1219.2	48.000	0.216
54	1371.6	54.000	0.243

[A] Special sizes.

5.3.1 *Short-Term Pressurization*—The pipe shall not rupture, leak, nor exhibit localized deformation when tested in accordance with 6.2.1 at the pressures given in Table 1(b).

5.3.2 *Alternate Elevated Temperature Sustained Pressure Test*—The average failure time and the failure time of two of the three specimens shall meet or exceed the minimum values shown in Table 11 when tested in accordance with 6.2.3.1.

5.3.3 *Sustained Pressure*—The pipe shall not rupture, leak, nor exhibit localized deformation (ballooning) when tested in accordance with 6.2.2 for a period of 1000 h at the pressure given in Table 1(c).

5.3.4 *Elevated Temperature Sustained Pressure*—The average failure time must meet or exceed the specified minimum average failure time in Table 3 for both hoop stresses of a given pipe test category, when tested in accordance with 6.2.3.

TABLE 7 Outside Diameters and Tolerances

DIPS Sizing System			
Nominal DIPS Sizes, in.	Equivalent, mm	Acutal Outside Diameters, in.	
		Average	Tolerance ± in.
3	100.6	3.96	0.016
4	121.9	4.80	0.022
6	175.3	6.90	0.031
8	229.9	9.05	0.041
10	281.9	11.10	0.050
12	385.3	13.20	0.059
14	388.6	15.30	0.069
16	442.0	17.4	0.078
18	495.3	19.5	0.088
20	548.6	21.60	0.097
24	655.3	25.80	0.116
30	812.8	32.00	0.144
36	972.8	38.30	0.172
42	1130.3	44.50	0.200
48	1290.3	50.80	0.229

TABLE 8 Minimum Wall Thickness ISO 161 Sizing System, mm

DR	41	32.5	26	21	17	11
Nominal Pipe Size						
90	. . .	. . .	3.5	4.3	5.3	8.2
110	. . .	3.4	4.2	5.2	6.5	10.0
160	. . .	4.9	6.2	7.6	9.4	14.5
200	. . .	6.2	7.7	9.5	11.8	18.2
250	. . .	7.7	9.6	11.9	14.7	22.7
280	. . .	8.6	10.8	13.3	16.5	25.5
315	. . .	9.7	12.1	15.0	18.5	28.6
355	. . .	10.9	13.7	16.9	20.9	32.3
400	. . .	12.3	15.4	19.0	23.5	36.4
450	. . .	13.8	17.3	21.4	26.5	. . .
500	. . .	15.4	19.2	23.8	29.4	. . .
560	. . .	17.2	21.5	26.7	32.9	. . .
630	. . .	19.4	24.2	30.0	37.1	. . .
710	. . .	21.8	27.3	33.8	41.8	. . .
800	. . .	24.6	30.8	38.1	47.1	. . .
900	. . .	27.7	34.6	42.9	. . .	. . .
1000	24.4	30.8	38.5	47.6	. . .	. . .
1200	29.3	36.9	46.2	. . .	. . .	. . .
1400	34.1	43.1	. . .	. . .	. . .	. . .
1600	39.0	49.2	. . .	. . .	. . .	. . .

5.4 *Apparent Tensile Strength at Yield*— For pipe sizes above 3-in. (90-mm) nominal diameter, the Short-Term Pressurization Test, 6.2.1, may be replaced by the apparent ring tensile strength test (Test Method D 2290). The minimum apparent tensile strength at yield when determined in accordance with 6.2.4 shall be 2520 psi (17.4 MPa).

6. Test Methods

6.1 *Raw Material Categorization*—Samples of polyethylene compounds for use in the manufacture of pipe under this specification shall be converted into pipe specimens under controlled manufacturing conditions. Specimens shall be measured in accordance with Test Method D 2122 to determine the average diameter throughout and the minimum wall thickness. Tests shall be conducted in accordance with Test Method D 1598 at 23°C in a "water inside-water outside'' or "water inside-air outside'' environment. The number of failure points and the period of testing shall be in accordance with Test Method D 2837.

NOTE 6—It is recommended that HDB for material categorization be calculated using hydrostatic test values obtained from the testing of specimens from 3.54 to 7.87 in. (90 to 200 mm) in diameter.

NOTE 7—The hydrostatic design basis, recommended by the Plastics Pipe Institute, may be used in pressure rating of pipe manufactured to this specification.

6.2 *Product Requirements Tests:*

6.2.1 *Short-Term Pressurization Tests*—These shall be conducted in accordance with Test Method D 1599 except that no failure will have occurred when the test pressure is raised to the value given in Table 1(b) in the prescribed period. The test shall be conducted at 73.4 ± 3.6°F (23 ± 2°C).

6.2.2 *Sustained Pressure Tests*—These shall be conducted in accordance with Test Method D 1598. The test pressure shall be given in Table 1(c). Tests shall be conducted in either a "water inside-water outside'' or" water inside-air outside'' environment at 73.4 ± 3.6°F (23 ± 2°C).

NOTE 8—**Precaution:** Pressurization of specimens being tested under 6.2.1 or 6.2.2 should not commence until it is certain that all entrapped air has been bled from the water-filled specimens.

6.2.3 *Elevated Temperature Test*—Determine pipe test category in Table 3 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 specimens as in 6.2.2. Test at 176°F (80°C) and the hoop stress (*S*) specified in Table 3 for the given pipe category in accordance with Test Method D 1598. Two or three specimens must meet or exceed the specified minimum average failure time. Use water as the internal test medium.

6.2.3.1 Prepare at least three specimens as in 7.5 for the appropriate test hoop stress given in Table 11. Test at 176°F (80°C) and the hoop stresses given in Table 11 in accordance with Test Method D 1598.

6.2.4 *Apparent Tensile Properties*—The procedure and test equipment shall be as specified in Test Method D 2290. Cut specimens from pipe. Test a minimum of five specimens. This method is applicable to all pipe of nominal 3-in. (90-mm) outside diameter and larger.

7. Retest and Rejection

7.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in the specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

8. Certification

8.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification, and has been

TABLE 9 Minimum Wall Thickness
IPS Sizing System, in. (ANSI B 36.10)

		Dimension Ratio											
Nominal IPS Pipe Size	Actual Pipe Size	41	32.5	26	21	17	15.5	13.5	11	9.3	9	8.3	7.3
3	3.500	0.085	0.108	0.135	0.167	0.206	0.226	0.259	0.318	0.376	0.389	0.422	0.479
4	4.500	0.110	0.138	0.173	0.214	0.265	0.290	0.333	0.409	0.484	0.500	0.542	0.616
5[A]	5.375	0.131	0.165	0.207	0.256	0.316	0.347	0.398	0.489	0.578	0.597	0.648	0.736
5	5.563	0.136	0.171	0.214	0.265	0.327	0.359	0.412	0.506	0.598	0.618	0.670	0.762
6	6.625	0.162	0.204	0.255	0.315	0.390	0.427	0.491	0.602	0.712	0.736	0.798	0.908
7[A]	7.125	0.174	0.219	0.274	0.340	0.420	0.460	0.528	0.648	0.766	0.792	0.858	0.976
8	8.625	0.210	0.265	0.332	0.411	0.507	0.556	0.639	0.784	0.927	0.958	1.039	1.182
10	10.750	0.262	0.331	0.413	0.512	0.632	0.694	0.796	0.977	1.156	1.194	1.295	1.473
12	12.750	0.310	0.392	0.490	0.607	0.750	0.823	0.944	1.159	1.371	1.417	1.536	1.747
13[A]	13.375	0.326	0.412	0.514	0.637	0.787	0.863	0.991	1.216	1.438	1.486	1.611	1.832
14	14.000	0.341	0.431	0.538	0.667	0.824	0.903	1.037	1.273	1.505	1.556	1.687	1.918
16	16.000	0.390	0.492	0.615	0.762	0.941	1.032	1.185	1.455	1.720	1.778	1.928	2.192
18	18.000	0.439	0.554	0.692	0.857	1.059	1.161	1.333	1.636	1.935	2.000	2.169	2.466
20	20.000	0.488	0.615	0.769	0.952	1.176	1.290	1.481	1.818	2.151	2.222	2.409	...
21.5[A]	21.500	0.524	0.662	0.827	1.024	1.265	1.387	1.593	...	...	...	...	...
22	22.000	0.537	0.677	0.846	1.048	1.294	1.419	1.630	2.000	2.366	2.444	...	...
24	24.000	0.585	0.738	0.923	1.143	1.412	1.548	1.778	2.182	2.581	2.667	...	...
26	26.000	0.634	0.800	1.000	1.238	1.529	1.677	1.926	2.364	2.796	...	...	...
28	28.000	0.683	0.862	1.077	1.333	1.647	1.806	2.074	2.545	3.011	...	...	...
30	30.000	0.732	0.923	1.154	1.429	1.765	1.935	2.222	2.727	3.226	...	...	...
32	32.000	0.780	0.985	1.231	1.524	1.882	2.065	2.370	2.909	...	...	...	...
34	34.000	0.829	1.046	1.308	1.619	2.000	2.194	2.519	3.091	...	...	...	...
36	36.000	0.878	1.108	1.385	1.714	2.118	2.323	2.667	3.273	...	...	...	...
42	42.000	1.024	1.292	1.615	2.000	2.471	2.710	...	...	...	...	...	...
48	48.000	1.171	1.477	1.846	2.286	2.824	3.097	...	...	...	...	...	...
54	54.000	1.317	1.662	2.077	2.571	3.176	...	...	...	...	...	...	...

[A] Special sizes.

TABLE 10 Minimum Wall Thickness

DIPS Sizing System, in.								
Nominal DIPS Pipe Size	Actual OD[A] Pipe Size	Dimension Ratio						
		41	32.5	26	21	17	13.5	11
3	3.96	...	0.122	0.153	0.189	0.233	0.294	0.360
4	4.80	0.117	0.148	0.185	0.229	0.283	0.356	0.437
6	6.90	0.168	0.213	0.266	0.329	0.406	0.512	0.628
8	9.05	0.221	0.279	0.348	0.431	0.533	0.670	0.823
10	11.10	0.236	0.342	0.427	0.529	0.653	0.823	1.009
12	13.20	0.322	0.407	0.508	0.629	0.777	0.978	1.200
14	15.30	0.373	0.471	0.589	0.729	0.900	1.134	1.391
16	17.40	0.424	0.536	0.670	0.829	1.024	1.289	1.582
18	19.50	0.463	0.600	0.750	0.929	1.147	1.445	1.773
20	21.60	0.527	0.665	0.831	1.029	1.271	1.600	1.964
24	25.80	0.629	0.794	0.993	1.229	1.518	1.912	2.346
30	32.00	0.780	0.985	1.231	1.524	1.883	2.371	2.909
36	38.30	0.934	1.179	1.473	1.824	2.253	2.837	3.482
42	44.50	1.085	1.370	1.712	2.119	2.618	3.297	4.046
48	50.80	1.239	1.563	1.954	2.419	2.989	3.763	4.619

[A] In accordance with Table 7.

TABLE 11 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

found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished. Each certification so furnished shall be signed by an authorized agent of the manufacturer.

9. Marking

9.1 Marking on the pipe shall include the following and shall be placed at least at each end of each shipped length of pipe or spaced at intervals of not more than 5 ft (1.5 m).

9.1.1 The letters ASTM followed by the designation number of this specification.

9.1.2 The letters PE followed by the cell classification number (D 3350) of the raw material compound used. Where the option of use of the 1450-psi (10-MPa) HDB classification has been taken, the position of the sixth digit shall be filled with a dash (–) followed by the notation 10 MPa. Where applicable, the standard thermoplastic pipe materials designation code (Appendix X4) may be used as an alternative marking.

9.1.3 Nominal pipe outside diameter in mm or inches in accordance with Table 5, Table 6, or Table 7, and the designated sizing system: "XX mm ISO," or" XX in IPS," or "XX in DIPS." For metric outside diameter pipe, "ISO" may be omitted, and for inches outside diameter pipe," in" may be replaced with a double-quotation mark (").

9.1.4 Dimensional ratio or pressure rating, or both, kilopascals or pound-force per square inch shown as "XXX kPa'' or "XXX psi''.

9.1.5 Name or trademark of the manufacturer.

9.1.6 Production code from which location and date of manufacturer can be identified.

9.1.7 Pipe intended for the transport of potable water shall also include the seal or mark of the accredited laboratory. (See Note 4.)

9.1.8 Pipe test category in accordance with Table 3.

9.2 *Using Color to Identify Piping Service*—It is not mandatory to use color to identify piping service, but when color is applied expressly to identify piping service, such as with stripes, a color shell or solid color, blue is used for potable water; green is used for sewer; and purple (violet, lavender) is used for reclaimed water.

10. Quality Assurance

10.1 When the product is marked with this designation, F 714, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a regulatory authority or user calls for the product to be used to convey or to be in contact with potable water.

S1. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S2. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE 9—In federal contracts, the contractor is responsible for inspection.

S3. *Packaging and Marking for U.S. Government Procurement*

S3.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Un iform Freight Classification rules on National Motor Freight Classification rules.

S3.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE 10—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

APPENDIXES

(Nonmandatory Information)

X1. General Information

X1.1 It has been demonstrated that pipe stiffness is not a controlling factor in design of buried polyethylene piping systems installed in accordance with Practice D 2321or equivalent recommended practices **(1–15)**[10].

X1.1.1 For those wishing to use deflection control in unpressurized polyethylene piping systems for construction specification purposes, the following information is provided.

[10] The boldface numbers in parentheses refer to the list of references at the end of this specification.

X2. DEFLECTION CONTROL IN UNPRESSURIZED POLYETHYLENE PIPING SYSTEMS

X2.1 Control of deflection is achieved primarily through control of the earthwork surrounding buried systems. Practice D 2321 should be followed to achieve this control. All dimensions of pipe specified in this specification may be successfully installed if this practice is followed.

X2.2 When polyethylene pipe is to be installed by insertion into older existing pipes or is to be laid where no support from the surrounding environment is possible, Practice F 585 should be followed in making a selection of appropriate dimension ratio pipe from this specification.

X2.3 The appropriate degree of deflection in buried piping may be calculated using the modified Spangler formula.

$$X = \frac{D_e\, K\, W_c}{0.149\ \mathrm{PS} + 0.061\ \mathrm{E}^1}$$

where:

X = deflection (horizontal or vertical), in. (or mm),
K = bedding constant, dependent on the support the pipe receives from the bottom of the trench (dimensionless),
D_e = deflection lag factor (dimensionless),
W_c = vertical load per unit of pipe length, lbf/in. (or N/m) of pipe,
PS = pipe stiffness = $4.472E/(\mathrm{SDR}-1)^3$ where E is the flexural modulus of its pipe material (see Section 4 of this specification), psi (or kPa), and
E^1 = modulus of soil reaction, depending on soil strength and degree of compaction, psi (or kPa).

NOTE X2.1—Pipe stiffness (PS) may also be determined by measurement for datum at a constant 5 % deflection by Test Method D 2412. See appendix to Test Method D 2412 for correction of this test value to other deflection levels.

X2.4 For purposes of this calculation, the pipe stiffness values given in Table X2.1 may be used. For specific data on particular products, consult the manufacturer's literature.

TABLE X2.1 Pipe Stiffness Ranges for Specified Materials and DR's, psi

DR	41	32.5	26	21	17	11
Modulus, Cell Classification						
3	2–6	6–11	11–23	22–45	71–87	179–358
4	6–8	11–16	23–31	45–61	87–120	358–492
5	8–11	16–23	31–46	61–89	120–175	492–716

X3. ALLOWABLE DEFLECTION LIMITS

X3.1 Research reports, including case histories supporting the following information, are on file at ASTM Headquarters.

X3.2 When said support is achieved, polyethylene pipes made to this specification may deflect or otherwise distort without kinking or buckling, and remain structurally stable up to 20 % or more of the vertical diameter. However, the lower the DR, the lower is the amount of deflection which should be permitted to ensure that long-term structural integrity is maintained. The pipe manufacturer should be consulted for the safe value for the particular pipe material involved. In the absence of specific data on a particular pipe material, Table X3.1 provides safe values for conventional polyethylene pipe materials. These values provide a safety factor of at least two against loss of structural integrity.

X3.3 If there is *no* external support around the pipe, structural integrity of the pipe is likely to be lost due to buckling if deflection exceeds 10 %. For selection of proper DR, see Practice F 585.

TABLE X3.1 Allowable Deflection of Buried Polyethylene Pipe, Short Term, %

DR	Allowable Deflection
41	10.9
32.5	8.6
26	6.5
21	5.0
17	4.0
11	3.3

X3.4 When polyethylene piping is subject to live external loading at buried depths of less than 4 ft (1200 mm), special precautions to ensure strong supporting soil conditions should be taken.

X3.5 Polyethylene pipes having high DR's will require more careful handling in storage, transport, and installation to avoid inducing pre-installation deflection. Kinking of pipe should be considered destructive damage and sections which have been kinked should not be installed, even though no leakage is observed.

X4. STANDARD THERMOPLASTIC PIPE MATERIALS DESIGNATION CODE

X4.1 The pipe materials designation code shall consist of the abbreviation PE for the type of plastic, 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. 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.

X5. QUALITY CONTROL

X5.1 Visual inspection of every length of pipe for workmanship defects shall be carried out at the manufacturer's plant. Measurements of outside diameter and wall thickness shall be made for each hour's production or each length of pipe, whichever is less frequent. Tests for apparent tensile properties shall be carried out as agreed upon between the manufacturer and the purchaser.

X5.2 Lengths of pipe that are shorter than standard shipping lengths may be butt-fused to produce standard lengths. Such built-up lengths must otherwise meet all of the product requirements of Section 5 of this specification.

X5.3 Manufacturers of pipe shall conduct such other quality control tests as are appropriate to their manufacturing operations and which will provide assurance that the product requirements of 5.3 will be met instead of the actual performance of the specified tests.

NOTE X5.1—The pressure tests required under product requirements are tests for performance. These tests are not adaptable to inplant quality control. Quality control tests have not been standardized because the requirements for such tests vary substantially from one manufacturing plant to another.

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Designation: F 1055 – 98$^{\epsilon 1}$

An American National Standard

Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing[1]

This standard is issued under the fixed designation F 1055; 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.

ϵ[1] NOTE—Keywords were editorially added in November 2003.

1. Scope

1.1 This specification covers electrofusion polyethylene fittings for use with outside diameter-controlled polyethylene pipe, covered by Specifications D 2447, D 2513, D 2737, D 3035, and F 714. Requirements for materials, workmanship, and testing performance are included. Where applicable in this specification “pipe” shall mean “pipe” or “tubing.”

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

1.3 The following safety hazards caveat pertains only to the test method portion, Section 9, 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 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 638 Test Method for Tensile Properties of Plastics[2]

D 1248 Specification for Polyethylene Plastics Molding and Extrusion Materials[2]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology Relating to Abbreviations, Acronyms, and Codes for Terms Relating to Plastics[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2447 Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter[3]

D 2513 Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings[3]

D 2737 Specification for Polyethylene (PE) Plastic Tubing[3]

D 3035 Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter[3]

D 3350 Specification for Polyethylene Plastic Pipe and Fittings Materials[4]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 714 Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter[3]

F 905 Practice for Qualification of Polyethylene Saddle Fusion Joints[3]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *electrofusion*—a heat fusion joining process where the heat source is an integral part of the fitting, such that when electric current is applied, heat is produced that melts and joins the plastics.

3.2.2 *fusion interface*—surface in the heat fusion process where the plastic materials of the products being joined bond together.

3.2.3 *fusion zone length*—total length of the melted material in the fitting cross-section under evaluation.

4. Materials and Manufacture

4.1 This specification covers fittings made from polyethylene compounds as defined in Specifications D 1248 or D 3350.

4.2 *Rework Material*—Clean rework polyethylene material of the same resin, free of any wire or contaminants generated from the fitting manufacturer’s own production, may be used

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards,* Vol 08.01.

[3] *Annual Book of ASTM Standards,* Vol 08.04.

[4] *Annual Book of ASTM Standards,* Vol 08.02.

by the same manufacturer, as long as the fittings produced conform to the requirements of this specification.

4.3 *Heating Mechanism*—The heat mechanism shall be of materials not detrimental to the performance of the fitting or the pipe to which it is intended to be joined.

5. Performance Requirements

5.1 The following requirements are for electrofusion joints that have been joined using the manufacturer's recommended joining procedures. These requirements must be met by each electrofusion joint design, on each size and type of pipe material for which the manufacturer recommends use of his fitting. Any revisions to the electrofusion joint design or processing by the manufacturer after the initial testing requires retesting to ensure these requirements can still be met. Fittings intended for use in the distribution of natural gas or liquid petroleum gas shall also meet the requirements of Specification D 2513.

5.1.1 It is not required that each configuration of a fitting be tested to meet all of these qualifications (that is, 2 in. main saddle joint with multiple outlet configurations offered) as long as the electrofusion joint design is not altered in the configuration differences.

NOTE 1—It is permissible when accomplishing these tests, to do so on the highest and lowest dimension ratio of the same pipe material. If in those tests all performance requirements are met, all dimension ratios between those tested may be considered as having met the requirements. These tests do not have to cover the full range of dimension ratios available, only the dimension ratio range on which the manufacturer recommends his fitting be used.

5.2 *Pressure Requirements*:

5.2.1 *Minimum Hydraulic Burst Pressure*— The minimum hydraulic burst pressure of the test specimen shall not be less than that required to produce 2520 psi (17.4 MPa) fiber stress in the pipe being used in the test when tested in accordance with 9.1. The test equipment, procedures, and failures definitions shall be as specified in Test Method D 1599.

5.2.2 *Sustained Pressure*—The fitting and fused joint shall not fail when tested in accordance with 9.2.

5.3 *Tensile Strength Requirements (Coupling Type Joints Only)*—The fitting or the pipe to fitting joint made on pipe shall not fail when tested in accordance with 9.3. Specimens shall be subjected to a tensile stress that causes the pipe to yield to an elongation no less than 25 % or causes the pipe to break outside the joint area. Tensile tests must be made on specimens as joined, not on straps cut from the specimen. Yielding must be measured only in the pipe, independent of the fitting or joint.

5.4 *Impact Resistance (Saddle Type Joints Only)*—The joint made on the specimen shall not fail when impacted with a force sufficient to break the body or other portion of the specimen. Tests of 500 ft·lbf or higher impact with no failures noted shall be considered as a "pass" impact test. The device for testing and the methods shall be as defined in Practice F 905.

5.5 *Joint Integrity Tests*—(*Couplings and Saddle Type Joints*)—The joint made on the specimen shall meet the requirements in 9.4 and 9.5 of this specification, when tested in accordance with 9.4.

6. Dimensions, Mass, and Permissible Variations

6.1 Dimension and tolerances of electrofusion fittings must be such that heat fusion is possible to outside diameter (OD) controlled PE pipes such as those listed in Specifications D 2447, D 2513, D 2737, D 3035, and F 714, such that the joints will satisfy the performance requirements in Section 5.

6.2 Because of the varying designs for electrofusion fittings, the actual spread of dimensions may be quite different from manufacturer to manufacturer. A table of dimensions and tolerances encompassing these differences would be meaningless and without value and, therefore, is omitted from this specification.

6.3 The manufacturer shall furnish to the user the electrical resistance, critical dimensions, and tolerances of his fittings. This information must include at least the following dimensions and tolerances:

6.3.1 Coupling inside diameter,

6.3.2 Temperature joining limits, and

6.3.3 Operating pressure of the fitting.

NOTE 2—There are other items that fall beyond the scope of this specification which would be of interest to the user for proper application of the fittings and is recommended as additional information to be furnished. A few of these are: (*1*) maximum pipe out of round allowed at joint area; (*2*) minimum/maximum pipe SDR capability of the fitting, and (*3*) for saddles intended for use on a live main, the maximum allowable line pressure when making the joint.

7. Workmanship, Finish, and Appearance

7.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification.

7.2 The fittings shall be homogeneous throughout, except where a heating coil or electrical connectors are incorporated, and free of cracks, holes, foreign inclusions, or injurious defects such as gouges, dents, cuts, etc. The fittings shall be as uniform as commercially practicable in opacity, density, and other physical properties. Any heating coils, connecting cables, connectors, and related electrical power source shall be designed to prevent electrical shock to the user.

8. Specimen Preparation

8.1 *Conditioning*:

8.1.1 Unless otherwise specified, condition the specimens (pipe and fittings) prior to joining at the minimum pipe temperature allowable for fusion as recommended by the manufacturer, for not less than 16 h and make the fusion joint at that temperature for those tests where conditioning is required.

8.1.2 Unless otherwise specified, condition the specimens (pipe and fittings) prior to joining at the maximum pipe temperature allowable for fusion as recommended by the manufacturer, for not less than 16 h and make the fusion joint at that temperature for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct the tests at the Standard Laboratory Temperature of 23 ± 2°C (73.4 ± 3.6°F) unless otherwise specified.

8.3 *Preparation of Specimens for Testing*:

8.3.1 Prepare test specimens so that the minimum length of unreinforced pipe on one side of any fitting is equal to three times the diameter of the pipe, but in no case less than 12 in. (304 mm). It is permissible to test multiple fittings together provided they are separated by a minimum distance equal to three times the diameter of the pipe, but in no case less than 12 in. (304 mm).

8.3.2 Fuse all fitting outlets with the appropriate size pipe in accordance with the manufacturer's recommended procedures.

8.3.3 All saddle fusion joint specimens conditioned as in 8.1.2 and destined for quick burst testing as in 9.1 and sustained pressure testing as in 9.2, are to be joined with the pipe at no less than maximum allowable operating pressure of the pipe system or fitting, whichever is lowest, when being prepared for those tests. The pipe should be left under pressure for a time period not less than recommended by the manufacturer for cooling in the field prior to disturbing the joint. Saddle joint specimens destined for mechanical/destructive type tests such as impact as in 5.4 or crush tests as in 9.4, or specimens conditioned for cold temperature joining as in 8.1.1, may be made on unpressured pipe specimens.

9. Test Methods

9.1 *Minimum Hydraulic Burst Pressure Test*:

9.1.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.1.2 Test the specimens in accordance with Test Method D 1599.

9.1.3 Failure of the fitting or joint shall constitute specimen failure.

9.1.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed specimens joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.2 *Sustained Pressure Test*:

9.2.1 Select four fittings at random and prepare specimens in accordance with Section 8 of this specification. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.2.2 Test the specimens in accordance with Test Method D 1598. All tests shall be conducted at 80 ± 2°C. The assemblies are to be subjected to pipe fiber stresses of 580 psi (4.0 mPa) for 1000 h or 670 psi (4.6 mPa) for 170 h. Joint specimens shall not fail within these time periods. Any failures within these time periods must be of the pipe, independent of the fitting or joint and must be of a" brittle" type pipe failure, not "ductile." If ductile pipe failures occur, reduce the pressure of the test and repeat until 170- or 1000-h results or pipe brittle failures are achieved.

9.2.3 Failure of the fitting or joint shall constitute specimen failure.

9.2.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed-specimens-joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.3 *Tensile Strength Test*:

9.3.1 Select four fittings at random and prepare specimens in accordance with Section 8 with the exception that it is permissible, on pipe sizes above 4 in. (102 mm) IPS, if limits of tensile machine will not allow 25 % elongation with pipe specimens of three-pipe diameters, to test with free pipe lengths of 20 in. (304-mm) minimum. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.3.2 Test the specimens using the apparatus of Test Method D 638. Test at a pull rate of 0.20 in. (5.0 mm) per min, ±25 %.

9.3.3 Failure of the fitting or joint as defined in 5.3, shall constitute specimen failure.

9.3.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed specimens joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.4 *Joint Integrity Tests*—Illustrations of joint crush tests for socket type joints and saddles are offered in 9.4.1 and 9.4.2 as test methods that are useful as an evaluation of bonding strength between the pipe and fitting. Alternately, the fusion evaluation test (FET) offered in 9.4.3 and 9.4.4 may be used in lieu of the crush test. Similar test evaluations as specified in the contract or purchase order and as agreed upon by the purchaser and manufacturer are of equal value in performing such evaluations and may be substituted with such agreement.

9.4.1 *Joint Crush Test*:

9.4.1.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2 (Note 3).

NOTE 3—It is permissible to utilize in joint integrity testing, specimens from the quick-burst tests conducted in 9.1 after visually determining that neither the joint area nor the pipe segment to be crushed was a part of the failure mode in the quick-burst test.

9.4.1.2 Slit socket joints longitudinally as illustrated in Fig. 1 as near the centerline of the pipe as practical. Pipe lengths extending out of the socket may be cut back to a minimum of 3 in. (76 mm) for ease of placing in a vise.

9.4.1.3 Place each specimen half in a vise such that the outermost wire of coil is within 1.250 ± 0.125 in. (32 ± 3 mm) of vise jaws, with the jaws closing only on the pipe portion of the specimen (Fig. 2).

9.4.1.4 Tighten the jaws of the vise on the pipe until the inner walls of the pipe meet (Fig. 3). Repeat crush test on both halves and each end of specimen, at all ends, where a joint exists.

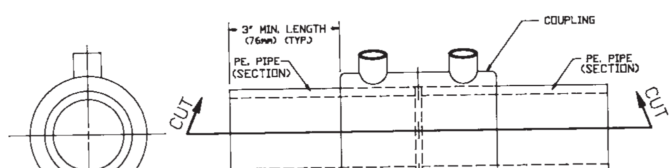

FIG. 1 Preparation of Coupling Specimen for Crush Test

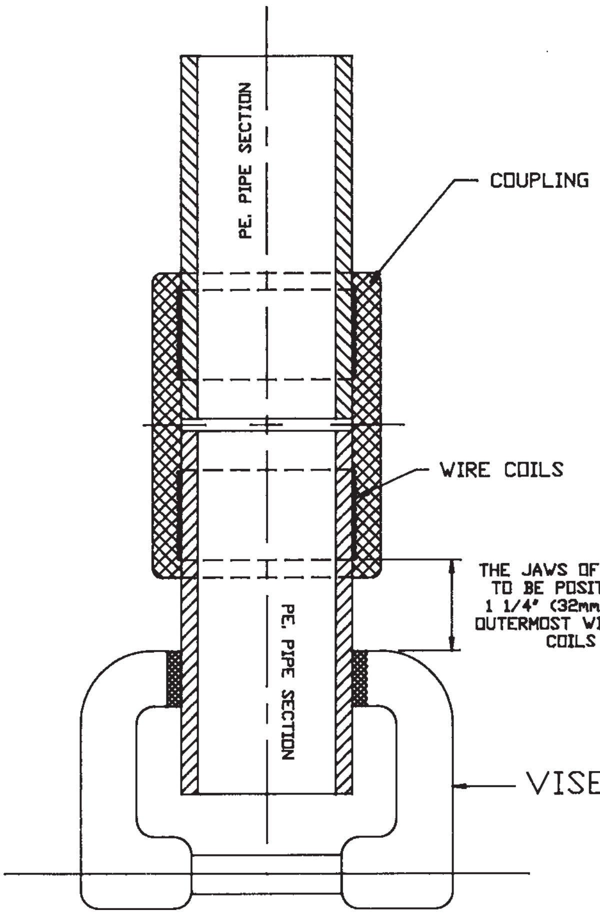

FIG. 2 Coupling Crush Test Arrangement

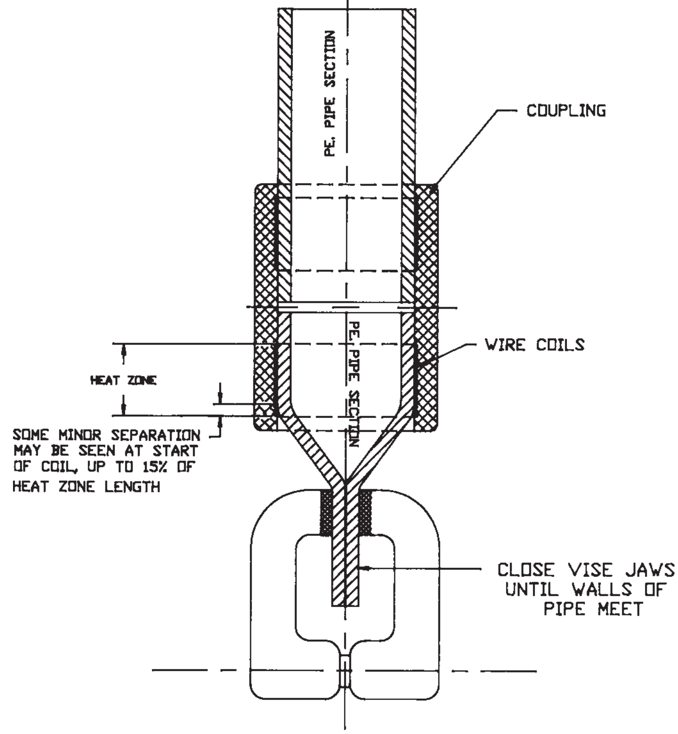

FIG. 3 Coupling Crush Test

9.4.1.5 Separation of the fitting from the pipe at the fusion interface constitutes a failure of the test. Some minor separation at the outer limits of the fusion heat source up to 15 % of the fusion length may be seen. This does not constitute a failure. Ductile failure in the pipe, fitting, or the wire insulation material, is acceptable as long as the bond interface remains intact.

9.4.1.6 Failure of any one of the four specimens shall constitute failure of the test and is cause for retest of four additional fittings, joined at the same temperature as the failed specimens. Failure of any of these four additional specimens constitutes a failure of the test.

9.4.2 *Saddle Type Joint Crush Test (Not Full-Wrap Design)*:

9.4.2.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2 (see 9.4).

9.4.2.2 Pipe lengths extending from saddle joint may be cut back clear up to the outer edges of the saddle for convenience of handling, if desired, however, it is not necessary. The length of the pipe extending beyond the saddle is not important to this test (Fig. 4).

9.4.2.3 Place the specimen in vise jaws as shown in Fig. 5, such that vise jaws are within ½ in. of saddle bottom and the jaws will close only on the pipe portion of the specimen. Saddle designs incorporating a bottom half saddle will need the bottom half removed for this test. Saddle designs incorporating a full-wrap single piece saddle are to be tested as in 9.4 socket type joints (Fig. 2 and Fig. 3).

9.4.2.4 Tighten the jaws of the vise on the pipe until the inner walls of the pipe meet (Fig. 6).

9.4.2.5 Separation of the fitting from the pipe at the fusion interface constitutes a failure of the test. Some minor separation at the outer limits of the fusion heat source up to 15 % of the fusion length may be seen. This does not constitute a failure. Ductile failure in the pipe, fitting, or the wire insulation material, is acceptable as long as the bond interface remains intact.

9.4.2.6 Failure of any one of the four specimens shall constitute failure of the test and is cause for retest of four additional fittings, joined at the same temperature as the failed specimens. Failure of any of these four additional specimens constitutes a failure of the test.

9.4.3 *Fusion Evaluation Test (FET) of Sockets*:

9.4.3.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.4.3.2 A band saw with a locking guide and a blade restricted to cutting plastic is recommended for obtaining the FET samples. Slit the socket in the order of cuts as illustrated in Fig. 7. First, radially cut the socket in half along the centerline of the joint. Pipe extending from the fittings may be cut back to about 1 in. from the fitting edge. Cut FET specimens approximately 1⁄16 in. wide from each joint half. A minimum of four FET strips shall be cut from one half of the socket and spaced approximately 90° apart.

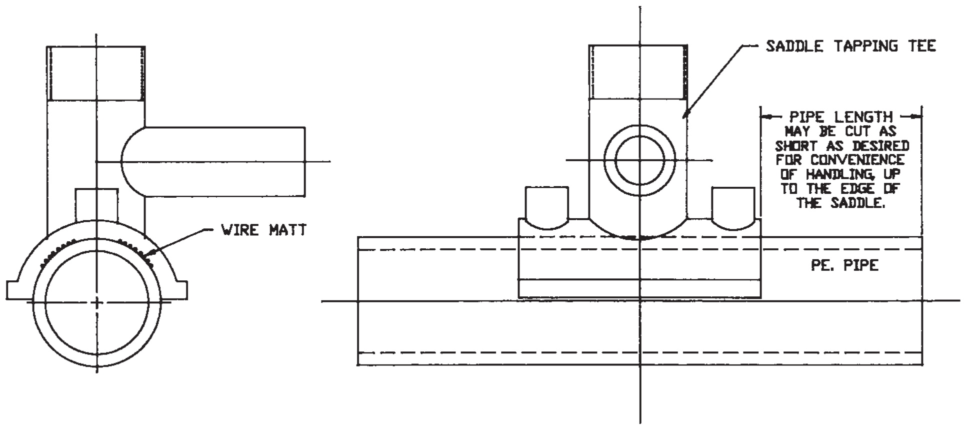

FIG. 4 Preparation of Saddle Specimen for Crush Test

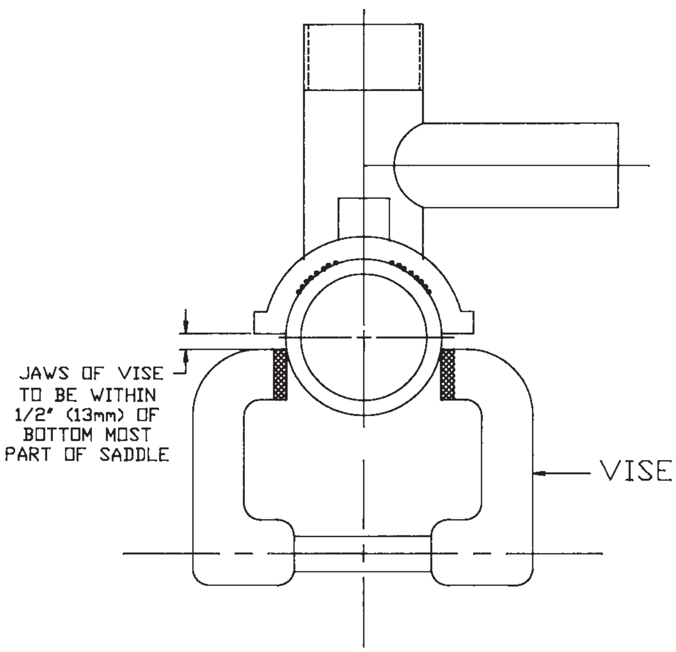

FIG. 5 Saddle Fitting Crush Test Before Crush

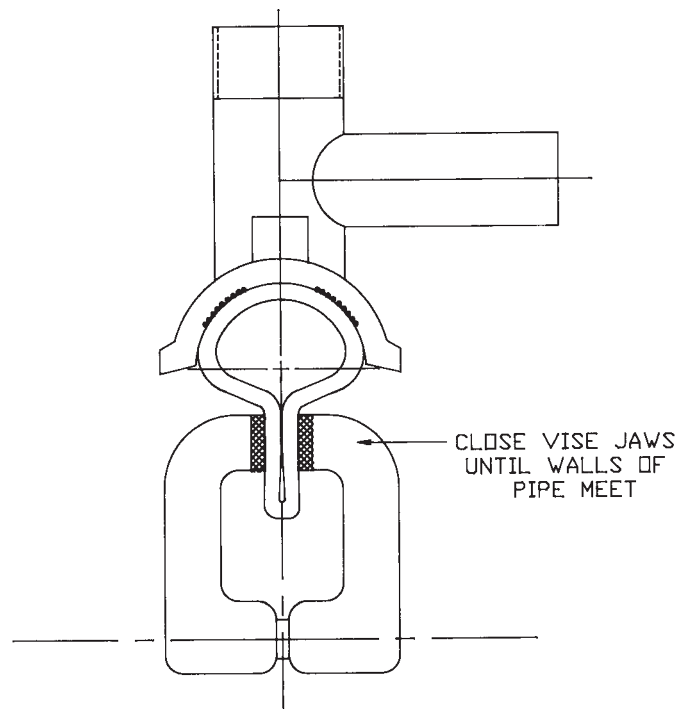

FIG. 6 Saddle Fitting Crush Test After Crush

9.4.3.3 Grip an FET specimen in a vise or clamping device as shown in Fig. 8 so that the bond line between the pipe and fitting is at least 1⁄16 in. from the edges of the clamping device. Flex the specimen four times 90° in both directions. Pliers may be used in lieu of a vise as long as the entire length of the fusion is flexed.

9.4.3.4 Separation of the specimen along the bond line constitutes failure of the specimen. Some minor separation at the outer limits of the fusion heat source may be seen or there may be voids between wires. This does not constitute failure as long as the voids do not exceed the limits of 9.5. Ductile failure in the pipe, fitting, or the wire insulation material is acceptable as long as the bond interface remains intact.

9.4.3.5 Failure of any one of the four joints shall constitute failure of the test and is cause for retest using four additional fittings joined at the same conditions as the failed joint specimens. Failure of any of these four additional joint specimens constitutes a failure in the test.

9.4.4 *Fusion Evaluation Test of Saddle Type Joints (Not Full-Wrap Design)*:

9.4.4.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.4.4.2 A band saw with a locking guide and a blade restricted to cutting plastic is recommended for obtaining the FET samples. Remove the stack from the fitting and cut the bottom portion of the pipe from the test piece. Cut the saddle in half in the transverse direction and then cut each half again in the longitudinal direction as shown in Fig. 9. Cut FET specimens approximately 1⁄16 in. wide through the fusion base of the saddle fitting. These cuts must be both longitudinal and transverse using two diagonal quarters for transverse direction and the two remaining quarters for the longitudinal direction.

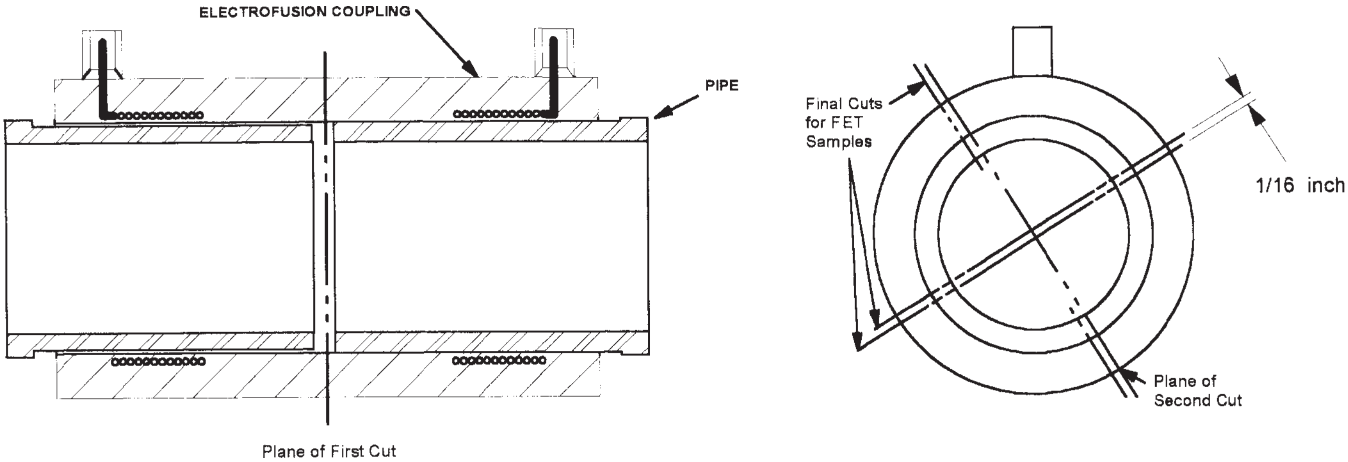

FIG. 7 Recommended Procedure for Cutting FET Strip From Coupling

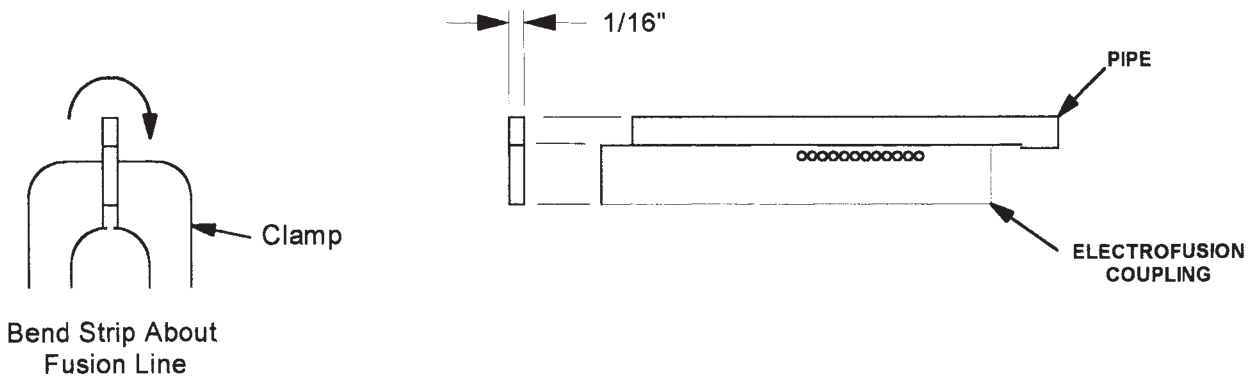

FIG. 8 Strip for FET Bend Test

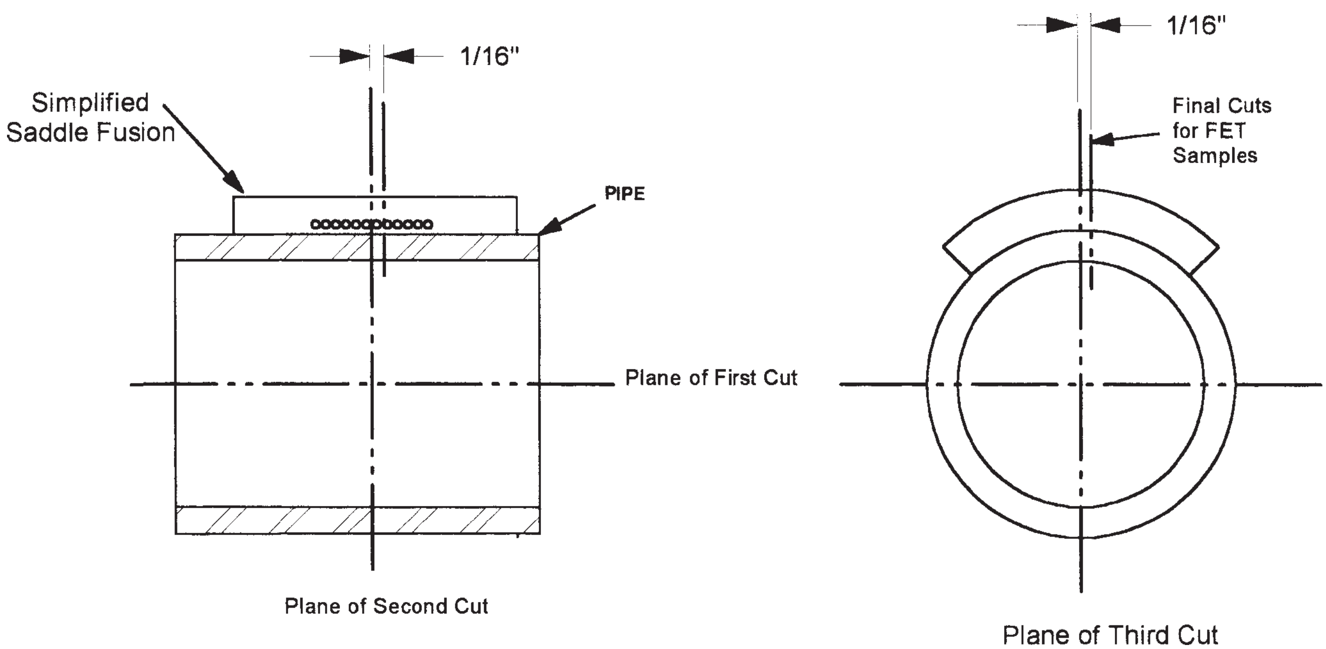

FIG. 9 Procedure for Cutting FET Strips from a Saddle

9.4.4.3 Inspect the fusion area for any discontinuities. Follow the instructions in 9.4.3.3 to test the FET samples.

9.4.4.4 Separation of the specimen along the bond line constitutes failure of the specimen. Some minor separation at the outer limits of the fusion heat source may be seen or there may be voids between wires. This does not constitute failure as long as the voids do not exceed the limits of 9.5. Ductile failure in the pipe, fitting, or the wire insulation material is acceptable as long as the bond interface remains intact.

9.4.4.5 Failure of any one of the four joints shall constitute failure of the test and is cause for retest using four additional fittings, joined at the same conditions as the failed joint specimens. Failure of any of these four additional joint specimens constitutes a failure in the test.

9.5 *Evaluation for Voids*—When dissecting electrofusion joints for the integrity tests in 9.4, or any reason, voids at or near the fusion interface may be exposed. The voids, should they be present, are a phenomenon of the electrofusion process, due to trapped air and shrinking during the cooling process after the joint is made. If detected, such voids are considered acceptable only if round or elliptical in shape, with no sharp corners allowed and if they meet the limitations of 9.5.1 through 9.5.3.

9.5.1 Voids that do not exceed 10 % of the fusion zone length in size are acceptable. (See Fig. 10.)

9.5.2 Multiple voids, if present, are acceptable if the combined void sizes do not exceed 20 % of the fusion zone length. (See Fig. 10.)

9.5.3 If voids are exposed, additional longitudinal cuts should be made to ensure that the void does not follow a diametric path which connects to the pressure-containing area of the joint. (See Fig. 11.)

NOTE 4—Some voids in electrofusion fitting joints may be due to the natural phenomenon described in 9.5. It is also possible the voids can be produced by not following proper fusion procedures. If voids are detected, one should ensure that all procedures were followed in making the joint.

10. Product Marking

10.1 Fittings shall be marked with the following:

10.1.1 Manufacturer's name or trademark,

10.1.2 Material designation (for example, PE2306, PE3408, etc.),

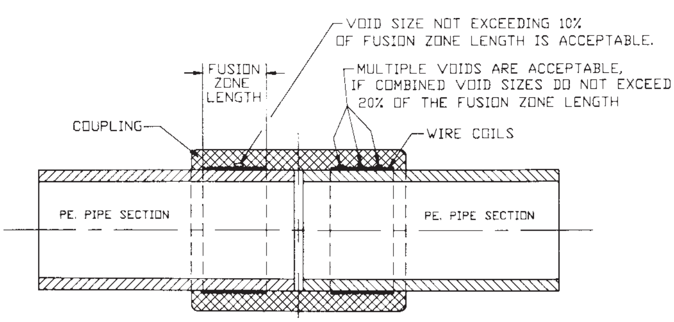

FIG. 10 Coupling Fusion Assembly With Possible Void Characteristics

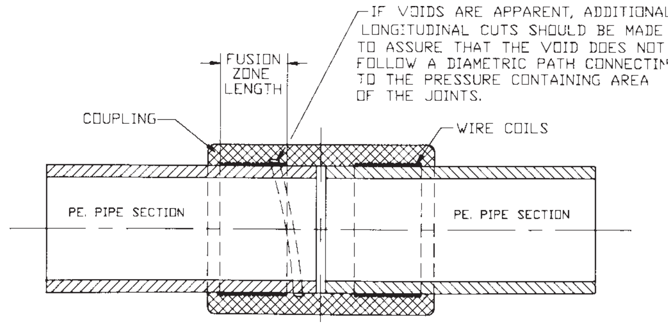

FIG. 11 Coupling Fusion Assembly—Further Examination Guidance

10.1.3 For fittings intended for transporting potable water, the seal of approval of an accredited laboratory, for fittings complying with Specification D 2513 and intended for gas distribution, the word "gas" or if space does not permit, the letter "G,"

10.1.4 Size, followed by "IPS" or "CTS" designation,

10.1.5 This designation ASTM F 1055,

10.1.6 The fittings shall bear an appropriate code number that will assure identification on the fittings as to date of production and resin formulas used in the production of said fittings. The manufacturer shall maintain such additional records as are necessary to confirm identification of all coded fittings, and

10.1.7 Where the size of the fitting does not allow complete marking, identification marking may be omitted in the following sequence: ASTM designation number, and material designation.

10.2 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices. If indentation is used, it shall be demonstrated that these marks have no effect on the long term strength of the fitting.

10.3 When the product is marked with this ASTM designation" F 1055,'' the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Quality Assurance

11.1 When the product is marked with this designation, F 1055 the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Keywords

12.1 electrofusion; fittings; joining; polyethylene

ANNEX

(Mandatory Information)

A1. IN-PLANT QUALITY CONTROL PROGRAM FOR ELECTROFUSION FITTINGS

A1.1 *Introduction:*

A1.1.1 Use the following in-plant quality control program, covering material and performance requirements in manufacture to provide reasonable assurance that the product meets the requirements of this specification and normally anticipated field performance requirements.

A1.2 *Fittings Tests:*

A1.2.1 Conduct the fittings tests at the frequencies indicated as follows:

NOTE A1.1—When any failure to meet the requirements of this specification occurs, make additional tests to ascertain those fittings that are acceptable, back to the last acceptable ones. Those that do not meet the requirements must be rejected.

A1.2.2 Dimensions of fusion area with heating element in place:

A1.2.2.1 *Socket Diameters*—Immediately proceeding production start up, then once per h, or one out of ten fittings, whichever is less frequent.

A1.2.2.2 *Saddle Sizes*—Main sizes and branching outlet sizes, immediately proceeding production start up, then once per h, or one out of ten fittings, whichever is less frequent.

A1.2.2.3 *Heating Element Resistance*—Immediately proceeding production start up, then once per h, or one out of ten fittings, whichever is less frequent.

A1.2.3 *Molding or Extrusion Quality*—Make the following tests on each cavity in the mold or each extrusion line being used. Test at the start of each production run, whenever production conditions have changed or when the resin lot has changed, but not less than once per 500 fittings thereafter.

A1.2.3.1 *Voids in Part*—Inspect for voids in the fitting by means of X-ray or dissection of the fitting in 0.25-in. (6-mm) wide strips.

A1.2.3.2 *Molding Knit Line Strength*—Test by one of the following tests, or other suitable tests:

(a) (*a*) By crushing a fitting or a portion of a fitting in a manner that applies load in a direction normal to the knit line.

(*b*) By performing an apparent tensile strength test of a ring cut from a fitting with the load oriented normal to the knit line.

(*c*) By performing a burst test of the fitting in accordance with Test Method D 1599.

NOTE A1.2—Separation in the knit line of any of these tests constitutes a failure of the test.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

Designation: F 2206 – 02

Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock[1]

This standard is issued under the fixed designation F 2206; 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.

1. Scope

1.1 This specification establishes requirements for fabricated fittings intended for use with outside-diameter controlled polyethylene pipe and tubing. These fittings are manufactured by heat-fusion joining shape-modified polyethylene components prepared from pipe, molded fittings, sheet, or block. Included are requirements for materials, design, workmanship, minimum dimensions, marking, test methods, and quality control.

1.2 Pressure rating of the fabricated-fitting design is beyond the scope of this standard and shall be established by the fitting manufacturer. This specification includes requirements for both room temperature and elevated temperature pressure-tests to demonstrate a reasonable level of performance of the fabricated-fitting design at the pressure rating established by the fitting manufacturer.

1.3 The pressure-tests requirements are specified by DR. The DR specified is that of the piping system for which the fabricated fitting is intended to be butt-fused.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units which are provided for information only and are not considered standard.

1.6 The following safety hazards caveat pertains only to the test methods portion, Section 9, 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 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[2]

D 2513 Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings[2]

D 3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing[2]

D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials[4]

F 412 Terminology Relating to Plastic Piping Systems[2]

2.2 *Federal Standards:*[5]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

OPS Part 192 Title 49, Code of Federal Regulations

2.3 *Military Standard:*[5]

MIL-STD-129 Marking for Shipment and Storage

2.4 *ANSI/NSF Standard:*[6]

ANSI/NSF 61 for Drinking Water System Components—Health Effects

3. Terminology

3.1 Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

3.2 *Definitions:*

3.2.1 *butt-fusion end(s)*, *n*—the butt end(s) of the fabricated fitting intended for field fusion by the installer.

3.2.2 *fabricated fitting*, *n*—a fitting constructed from manufactured polyethylene components or materials.

3.3 *Abbreviations:*

3.3.1 *DIPS*—ductile iron pipe size.

3.3.2 *DR*—dimension ratio.

3.3.3 *IPS*—iron pipe size.

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards*, Vol 08.04.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

3.3.4 *OD*—outside diameter.

4. Classification

4.1 *General*—This specification establishes requirements for fabricated fittings intended for butt-fusion joining to polyethylene pipe.

4.1.1 Fabricated fitting components may be machined from extruded polyethylene or molded polyethylene stock and heat-fused to form the final part.

4.1.2 Fabricated fittings intended for use in the distribution of natural gas or other fuel gases shall also meet the requirements of Specification D 2513.

5. Ordering Information

5.1 When ordering fittings under this specification include the following information:

5.1.1 Polyethylene compound (material designation or trade name).

5.1.2 Style of fitting (3 piece tee, 5 segment 90° ell, etc.).

5.1.3 Size:

5.1.3.1 Nominal size of end connections.

5.1.3.2 End configurations (for example, IPS or DIPS).

5.1.3.3 System design ratio.

6. Material

6.1 *Material Classification*—Polyethylene materials allowable for use in this specification shall be classified in accordance with Specification D 3350 as shown in Table 1. Consult with the manufacturer for cell classification applicable to their materials.

NOTE 1—Manufacturers should use appropriate quality assurance procedures to ensure that sheet, block and plate are free from voids, laminations, foreign inclusions, cracks, and other injurious defects.

7. Requirements

7.1 *Dimension and Tolerances*—Butt-fusion ends shall be produced from fittings or pipe conforming to Specification D 3261, or by machining block, sheet, plate, or pipe to the required dimensions.

7.1.1 *Diameter*—Nominal outside-diameter of the butt-fusion end shall conform to the IPS or DIPS dimension at area of fusion. Outer-diameter dimensions and tolerances at the area of fusion shall be as shown in Table 2 or Table 3.

7.1.2 *Wall Thickness*—The minimum wall thickness of the butt-fusion end shall be in accordance with Table 2 or Table 3 when measured in accordance with Test Method D 2122. Conditioning to standard temperature but not to standard humidity is required.

TABLE 1 Specification D 3350 Cell Classification Limits for Fitting Materials

D 3350 Cell Classification Property	Allowable D 3350 Cell Classification Units	
	PE2406	PE3408
Density	2	3
Melt Index	1-2-3-4	3-4-5
Flexural Modulus	4-5-6	4-5-6
Tensile Strength	2-3	3-4-5
Slow Crack-Growth Resistance	6	6
HDB	3	4
Color/UV Stabilizer	C-D-E	C-D-E

7.1.3 *Eccentricity*—The wall thickness variability of the butt-fusion end as measured and calculated in accordance with Test Method D 2122, in any diametrical cross-section of the pipe shall not exceed 12 %.

7.1.4 *Measurements*—These shall be made in accordance with Test Method D 2122 for roundable pipe.

7.1.5 *Laying Lengths*—Laying length dimensions shall be defined by the manufacturer.

7.1.6 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable for engineered applications when mutually agreed upon by the customer and the manufacturer, if the fitting is manufactured from plastic compounds meeting the material requirements of this specification, and the fitting performs in accordance with the requirements in this specification. For diameters not shown in Table 2 or Table 3, the tolerance shall be the same percentage as that shown in the corresponding tables for the next smaller listed size. Minimum wall thickness at the butt-fusion end for these special sizes shall not be less than the minimum wall thickness specified for the pipe the fitting is designed to be used with.

7.2 *Physical Requirements*—Fabricated fittings using miter cut pipe stock shall be manufactured from pipe stock with a wall thickness 25 % greater than that of the pipe to which the fitting is to be joined. (For example: A SDR11 fitting shall be made using SDR9 pipe stock.)

7.3 *Pressure Test Requirements*—One size and DR of each style fitting manufactured in each of the following size ranges—12 in. (300 mm) and smaller, greater than 12 to less than 24 in. (300 to less than 600 mm), and 24 in. (600 mm) and larger—in each particular material shall be evaluated. The size and DR of each style fitting selected shall be tested per 7.3.1 and 7.3.2. Fitting styles are characterized as elbows, tees, wyes, crosses, reducing tees, reducing laterals, branch saddles, flange adapters, mechanical joint adapters, and end caps.

7.3.1 *Sustained Pressure Test*—The fitting shall not fail, as defined in Test Method D 1598, when tested at the time, pressures, and test temperatures per Test A in Table 4. The test specimens shall be prepared for testing in the manner prescribed in 9.5.1.

7.3.2 *Elevated Temperature Sustained Pressure Test*—The fitting shall not fail, as defined in Test Method D 1598, when tested at the time, pressures, and test temperatures per Test B or Test C in Table 4. The test specimens shall be prepared for testing in the manner prescribed in 9.5.1.

8. Workmanship, Finish and Appearance

8.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8.2 The procedure used for the heat fusion in the fabrication process shall be written and qualified in accordance with the requirements of OPS 49 CFR Part 192.283 "Plastic Pipe: Qualifying Joining Procedures."

TABLE 2 IPS Sizing System: Butt-Fusion End Dimensions, in.

Size IPS	Average OD[A]	Minimum Wall Thickness[B] versus DR									
		7.3	9	9.3	11	13.5	15.5	17	21	26	32.5
2	2.38	. . .	0.26	. . .	0.22	0.18	. . .	0.14	. . .	. . .	. . .
3	3.500	0.479	0.389	0.376	0.318	0.259	0.226	0.206	0.167	0.135	0.108
4	4.500	0.616	0.500	0.484	0.409	0.333	0.290	0.265	0.214	0.173	0.138
5	5.563	0.762	0.618	0.598	0.506	0.412	0.359	0.327	0.265	0.214	0.171
6	6.625	0.908	0.736	0.712	0.602	0.491	0.427	0.390	0.315	0.255	0.204
8	8.625	1.182	0.958	0.927	0.784	0.639	0.556	0.507	0.411	0.332	0.265
10	10.750	1.473	1.194	1.156	0.977	0.796	0.694	0.632	0.512	0.413	0.331
12	12.750	1.747	1.417	1.371	1.159	0.944	0.823	0.750	0.607	0.490	0.392
14	14.000	1.918	1.556	1.505	1.273	1.037	0.903	0.824	0.667	0.538	0.431
16	16.000	2.192	1.778	1.720	1.455	1.185	1.032	0.941	0.762	0.615	0.492
18	18.000	2.466	2.000	1.935	1.636	1.333	1.161	1.059	0.857	0.692	0.554
20	20.000	. . .	2.222	2.151	1.818	1.481	1.290	1.176	0.952	0.769	0.615
22	22.000	. . .	2.444	2.366	2.000	1.630	1.419	1.294	1.048	0.846	0.677
24	24.000	. . .	2.667	2.581	2.182	1.778	1.548	1.412	1.143	0.923	0.738
26	26.000	. . .	. . .	2.796	2.364	1.926	1.677	1.529	1.238	1.000	0.800
28	28.000	. . .	. . .	3.011	2.545	2.074	1.806	1.647	1.333	1.077	0.862
30	30.000	. . .	. . .	3.226	2.727	2.222	1.935	1.765	1.429	1.154	0.923
32	32.000	. . .	. . .	. . .	2.909	2.370	2.065	1.882	1.524	1.231	0.985
34	34.000	. . .	. . .	. . .	3.091	2.519	2.194	2.000	1.619	1.308	1.046
36	36.000	. . .	. . .	. . .	3.273	2.667	2.323	2.118	1.714	1.385	1.108
42	42.000	. . .	. . .	. . .	. . .	. . .	2.710	2.471	2.000	1.615	1.292
48	48.000	. . .	. . .	. . .	. . .	. . .	3.097	2.824	2.286	1.846	1.477
54	54.000	. . .	. . .	. . .	. . .	. . .	. . .	3.176	2.571	2.077	1.662

[A] Tolerance on OD is ± 0.45 %.
[B] Eccentricity of wall shall not exceed 12 %.

TABLE 3 DIPS Sizing System: Butt-Fusion End Dimensions, in.

Size DIPS	Average OD[A]	Minimum Wall Thickness[B] versus DR						
		9	11	13.5	17	21	26	32.5
3	3.96	0.389	0.360	0.294	0.233	0.189	0.153	0.122
4	4.80	0.500	0.437	0.356	0.283	0.229	0.185	0.148
6	6.90	0.736	0.628	0.512	0.406	0.329	0.266	0.213
8	9.05	0.958	0.823	0.670	0.533	0.431	0.348	0.279
10	11.10	1.194	1.009	0.823	0.653	0.529	0.427	0.342
12	13.20	1.417	1.200	0.978	0.777	0.629	0.508	0.407
14	15.30	1.556	1.391	1.134	0.900	0.729	0.589	0.471
16	17.40	1.778	1.582	1.289	1.024	0.829	0.670	0.536
18	19.50	2.000	1.773	1.445	1.147	0.929	0.750	0.600
20	21.60	2.222	1.964	1.600	1.271	1.029	0.831	0.665
24	25.80	2.667	2.346	1.912	1.518	1.229	0.993	0.794
30	32.00	. . .	2.909	2.371	1.883	1.524	1.231	0.985
36	38.30	. . .	3.482	2.837	2.253	1.824	1.473	1.179
42	44.50	. . .	4.046	3.297	2.618	2.119	1.712	1.370
48	50.80	. . .	4.619	3.763	2.989	2.419	1.954	1.563

[A] Tolerance on OD is ± 0.45 %.
[B] Eccentricity of wall shall not exceed 12 %.

8.3 All personnel engaged in the heat fusion process shall be qualified in accordance with the requirements of OPS 49 CFR Part 192.285 "Plastic Pipe: Qualifying Persons to Make Joints."

9. Test Methods

9.1 *General*—The test methods in this specification apply to fittings for use with pipe and tubing for gas, water, and other engineered piping systems.

9.2 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73.4 ± 3.6°F (23 ± 2°C) for not less than 6 h in air or 1 h in water.

9.3 *Test Conditions*—Conduct the tests at the standard laboratory temperature of 73.4 ± 3.6°F (23 ± 2°C) unless otherwise specified.

9.4 *Dimensions and Tolerances*:

9.4.1 *Outside Diameter*—Measure the outside diameter of the fittings at the butt-fusion end in accordance with the Wall Thickness section of Test Method D 2122 by use of circumferential tape readable to the nearest 0.001 in. (0.02 mm). Other methods may be used if proven to be equivalent.

9.4.2 *Wall Thickness*—Make a series of measurements using a cylindrical-anvil tubular micrometer or other accurate device at closely spaced intervals to ensure that minimum and maximum wall thickness to the nearest 0.01 in. (0.2 mm) have been determined. Make a minimum of six measurements at each butt-fusion end.

9.5 *Pressure Testing*:

9.5.1 *Preparation of Specimens for Pressure Testing*—Test specimens may be individual fittings or groups of fittings.

9.5.2 *Sustained Pressure Test*:

9.5.2.1 Select the test temperature and pressure from Table 4 as required.

9.5.2.2 Select three test specimens per size range at random and condition the specimens at the specified test temperature.

TABLE 4 Sustained Pressure Test of Fabricated Fitting

Pipe System DR (all Dia.)	TEST A 73.4°F (23°C) for 1000 h		TEST B 176°F (80°C) for 1000 h	TEST C 176°F (80°C) for 170 h
	PE2406 psig (MPa)	PE3408 psig (MPa)	PE2406 / PE3408 psig (MPa)	PE2406 / PE3408 psig (MPa)
DR 7	440 (3.036)	535 (3.662)	195 (1.345)	225 (1.553)
DR 9	330 (2.277)	400 (2.760)	145 (1.001)	170 (1.173)
DR 9.3	320 (2.208)	385 (2.657)	140 (0.966)	160 (1.104)
DR 11	265 (1.829)	320 (2.208)	115 (0.794)	135 (0.932)
DR 11.5	250 (1.725)	305 (2.105)	110 (0.759)	130 (0.897)
DR 15.5	180 (1.242)	220 (1.518)	80 (0.552)	90 (0.621)
DR 17	165 (1.139)	200 (1.380)	75 (0.504)	85 (0.587)
DR 21	130 (0.897)	160 (1.104)	60 (0.414)	65 (0.449)
DR 32.5	85 (0.587)	100 (0.690)	35 (0.242)	40 (0.276)

NOTE 1—Test at 73.4°F (23°C) pipe equivalent fiber stress of 1320 psi (9 MPa) for PE2406. Pipe equivalent fiber stress of 1600 psi (11.02 MPa) for PE3408.

NOTE 2—1000 h elevated temperature test fiber stress of 580 psi (4.0 MPa) all materials.

NOTE 3—170 h elevated temperature test fiber stress of 670 psi (4.6 MPa) all materials.

NOTE 4—All psig values were rounded to nearest 5 psig.

Test the specimens with water in accordance with Test Method D 1598 at the specified temperature, stress, and test duration.

9.5.2.3 Failure of one of the three specimens shall constitute failure of the test.

10. Product Marking

10.1 Fittings shall be marked with the following:

10.1.1 This designation; "ASTM F 2206,"

10.1.2 Manufacturer's name or trademark,

10.1.3 Material designations (such as PE2406 or PE3408),

10.1.4 Date of manufacture or manufacturing code, and

10.1.5 Nominal size and pipe system DR.

10.2 Where recessed marking is used, such marking shall have no injurious effect on the product's performance.

11. Quality Assurance

11.1 When the product is marked with this designation, ASTM F 2206, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Keywords

12.1 fabricated fittings; polyethylene

SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a Regulatory Authority or user calls for the product to be used to convey or to be in contact with potable water.

S1. Potable Water Requirement

S1.1 Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply only to federal/military procurement, not domestic sales or transfers.

S2. Responsibility for Inspection

S2.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE 2—In federal contracts, the contractor is responsible for inspection.

S3. Packaging and Marking for U.S. Government Procurement

S3.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S3.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE 3—The inclusion of U.S. government procurement requirements should not be construed as an indication that the U.S. government uses or endorses the products described in this specification.

Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe

TR-33/2001

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Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe

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Foreword

This report was developed and published with the technical help and financial support of the members of the PPI (Plastics Pipe Institute, Inc.). The members have shown their interest in quality products by assisting independent standards-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

The purpose of this technical report is to provide important information available to PPI on a particular aspect of polyethylene pipe butt fusion to engineers, users, contractors, code officials, and other interested parties. More detailed information on its purpose and use is provided in the document itself.

This report has been prepared by PPI as a service of the industry. The information in this report is offered in good faith and believed to be accurate at the time of its preparation, but is offered without any warranty, expressed or implied, including WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Consult the manufacturer for more detailed information about the particular joining procedures to be used with its piping products. Any reference to or testing of a particular proprietary product should not be construed as an endorsement by PPI, which does not endorse the proprietary products or processes of any manufacturer. The information in this report is offered for consideration by industry members in fulfilling their own compliance responsibilities. PPI assumes no responsibility for compliance with applicable laws and regulations.

PPI intends to revise this report from time to time, in response to comments and suggestions from users of the report. Please send suggestions of improvements to the address below. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

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http://www.plasticpipe.org

June 2001

INTRODUCTION

In 1994, representatives of the U.S. DOT (Department of Transportation), Office of Pipeline Safety requested that the Plastics Pipe Institute (PPI) assist in promoting greater uniformity in the joining procedures utilized by gas utilities in the butt fusion of polyethylene (PE) gas piping products. DOT reported that it had encountered a proliferation of similar but slightly varying joining procedures from individual PE pipe producers. The slight differences in the various procedures made it more difficult for pipeline operators to qualify persons with appropriate training and experience in the use of these procedures. It was even more difficult for DOT to enforce the joining requirements in § 192.283 (Plastic pipe, qualifying joining procedures) of the C.F.R. (Code of Federal Regulations) Title 49.

In response to DOT's request, PPI established a task group to examine the differences among the varying joining procedures, to identify similarities in those procedures, and to determine whether there were a sufficient number of common elements to provide a basis for a more uniform, or "generic" joining procedure that could be qualified by pipeline operators for most applications. A more uniform joining procedure would bring greater consistency to this aspect of gas pipeline installation, facilitate the pipeline operators efforts to qualify the procedure, reduce costs, and simplify DOT's enforcement duties.

SCOPE

The program undertaken by the PPI Task Group for the testing of representative materials under a generic set of conditions was designed to reflect the fusion conditions and parameters specified in most joining procedures recommended by pipe producers and qualified by pipeline operators. It was intended to provide a technical basis for the development of a generic butt fusion procedure (see Appendix A) that can be offered to the industry for use with selected PE (polyethylene) piping products. The procedure would be available for use by pipeline operators who would determine whether the procedure is appropriate for use with the PE piping products it employs. Pipeline operators could consider the recommendations and testing performed by others in their effort to comply with the fusion procedure qualification requirements of 49 C.F.R. § 192.283 (Plastic pipe, qualifying joining procedures).

It is important to emphasize that the testing performed by the PPI Task Group was intended only to establish a technical basis for developing and proposing a more generic fusion joining procedure that would offer the maximum opportunity to be qualified and used by pipeline operators with a broad range of polyethylene piping products. The testing was not intended to qualify the procedure for use with any particular pipe product, and PPI offers no opinion on whether the procedure is properly qualified for use with any particular PE pipe product. PE pipe producers remain solely responsible for any representations that they may make about the use of this generic procedure or any other joining procedure with their proprietary PE piping products, and pipeline operators remain solely responsible for compliance with the requirements of 49 C.F.R. § 192.283 (Plastic pipe, qualifying joining procedures) when qualifying any procedure for use with the products it selects for its pipelines. PPI member pipe manufacturers have endorsed this generic procedure for joining their product to itself and to other commercially available pipe materials. Endorsement letters from Charter Plastics, CSR Polypipe, KWH Pipe, North American Pipe, Phillips Driscopipe, PLEXCO and Uponor are in Appendix B. Typical photographs of properly made butt fusion joints are in Appendix C.

PPI hopes that the inherent value of greater uniformity will provide all the incentive necessary for companies to evaluate the generic procedure in Appendix A as a first option for butt fusion joining of its PE piping products. Use of this procedure is obviously not mandatory, and every PE pipe producer and pipeline operator retains the option of developing different procedures for its particular products and pipelines. However, PPI believes that its work in developing this generic procedure as a candidate for widespread acceptance throughout the industry will lead to greater efficiency, simplicity, and understanding in this area and promote the use of effective, qualified procedures for butt fusion joining of PE pipe.

TESTING PROGRAM TO EVALUATE USE OF GENERIC JOINING PROCEDURE WITH POLYETHYLENE GAS PIPING PRODUCTS

The Task Group collected and examined a large number of diverse procedures now in use by gas pipeline operators or recommended by pipe producers for specific PE piping products. It then identified those conditions and fusion parameters that were common to the majority of those procedures. The Task Group proposed the following fusion parameters as representative of the conditions in the individual procedures that they reviewed:

Heater Surface temperature	400-450°F (204-232°C)
Interfacial Pressure	60-90 psi (4.14-6.21 bar)

From its review of the different procedures collected from PE gas pipe producers, the Task Group further developed the generic joining procedure set out in Appendix A, based on its assessment of the common elements in the individual procedures. It was agreed that proprietary products such as Uponor's Aldyl A MDPE products and Phillips Driscopipe's D8000 HDPE piping products were sufficiently different from the remainder of the materials being discussed that they were not included in the test program. The manufacturers should be contacted for more information on particular joining procedures for those products. Only current commercially available products (see Appendix B) from PPI member companies were included in this test program. For information on older or other products, please contact the manufacturer of those products.

Using these parameter ranges and procedures, the Task Group initiated a 3-part test program to evaluate whether a representative cross-section of marketed PE gas piping products would qualify under the qualification requirements of Part 192 when joined in accordance with this generic joining procedure. The evaluation was conducted using pipe from MDPE and HDPE materials deemed suitable for fuel gas applications per ASTM D2513. These materials have a grade designation, in accordance with ASTM D3350, of PE24 and PE34, respectively.

Grade	Density (Grams/cc)	Melt Index (Grams/10min.)	Pipe Marking
PE 24	.926 - .940	.15 to .40	PE 2406
PE 34	.941 - .955	.05 to .15	PE 3408

After fusion of the samples, tensile and quick-burst tests were conducted in accordance with the requirements of 49 C.F.R. § 192.283 (Plastic pipe, qualifying joining procedures). Non-destructive ultrasonic inspections and high speed tensile impact testing were also conducted on each fusion combination. Additional testing conducted only on 8" pipe samples, included 176° F (80°C), 1,000-hour long-term hydrostatic testing at 580 psi (40 bar) hoop stress. The results of the test program are described in the following sections. PPI's Conclusions and Recommendations, based on the Task Group's work, are found in Section IV. Test data are maintained at PPI headquarters.

Part 1 - Pipe Fusion and Testing - 2" IPS DR 11 (like materials)

Part 1 of this project was to evaluate the generic procedure for use in fusing a PE pipe producers product to itself (e.g., Phillips MDPE to Phillips MDPE). The Task Group members supplied 2" SDR 11 pipe samples for fusion joining.

A total of 24 sample fusions, like material to like material, were made for each MDPE and HDPE pipe product. The total number of sample pieces was 72 and the total number of fusion joints made was 290. To evaluate the fusion parameters initially selected by the Task Group, all combinations of min/max heater surface temperatures 400 - 450°F (204 -232°C) and min/max interfacial pressures 60—90 psi (4.14-6.21 bar) were used in this testing. In addition, sample fusions at heater face temperatures (375°F and 475°F) (191°C and 246°C) and interfacial pressures (50 and 100 psi) (3.45 and 6.90 bar) were made and tested to examine conditions for fusion outside the initially generic parameters. The Task Group agreed to use these same fusion parameters for both the MDPE and HDPE.

The results of testing these fusion samples were 100% positive. All of the fusion joints (including those made under the extended parameters) passed every test conducted. As noted above, these tests included tensile testing, quick burst testing, high speed tensile impact testing and 100% ultrasonic inspection.

Part 2 - Pipe Fusion and Testing -2" IPS DR11 (Unlike Materials)

Part 2 of this project was to evaluate the generic procedure, the fusion temperature range, and the interfacial pressure range for cross fusions of unlike materials (e.g., Phillips MDPE to PLEXCO MDPE or Uponor MDPE to KWH Pipe HDPE).

Again 2" IPS SDR11 PE pipe was chosen. The Task Group members reviewed the information presented in Table 1 and decided that the cross fusion program could be simplified by selecting representative materials only. For MDPE materials it was decided that two materials could be selected to represent the two main families of MDPE materials (chromium oxide/slurry loop produced MDPE and Unipol Gas Phase MDPE). The two specific materials selected were Phillips Marlex TR-418 and Union Carbide DGDA 2400. The testing of these two materials would help to assess the appropriateness of the generic conditions for cross fusion of all MDPE plastic pipe gas compounds commonly being used today. The Task Group decided to use the same joining parameters as in Part 1 in these tests, based on the view that successful fusions under these conditions would cover all the other materials under the generic ranges. The chosen combination of joining parameters were (1) 475°F/100 psi (246°C/6.90 bar) and (2) 375°F/50 psi (191°C/3.45 bar). The remainder of the fusion procedures remained the same as Part 1. Fusion joints between Phillips TR-418 and Union Carbide DGDA 2400 were prepared. There were nine (9) joints made at each joining parameter for a total of (18) joints.

For HDPE materials, the Task Group selected three (3) HDPE materials for evaluation: Chevron 9308, Novacor HD2007-H and Fina 3344. There were nine (9) joints made at each of the selected combinations of fusion parameters and combinations of materials, for a total of (54) joints.

For MDPE to HDPE joints, the Task Group elected to fuse Union Carbide 2400 to Fina 3344 to establish the cross fusion procedure for the fusion of MDPE to HDPE. Nine (9) joints were made at each of the two extended parameter combinations, for a total of (18) joints.

The results of testing these fusion samples were 100% positive. All of the fusion joints passed every test conducted. As noted above, these tests included tensile testing, quick burst testing, high speed tensile impact testing and 100% ultrasonic inspection.

Part 3 - Pipe Fusion and Testing - 8" IPS DR11 (Unlike Materials)

Part 3 of this project was to test 8" IPS SDR 11 PE pipe to establish a range of pipe sizes where the generic procedure could be used. For MDPE materials, the Task Group identified five different medium density polyethylene materials which can be classed into two main types based on catalyst family, production process and melt index:

A. Phillips Marlex TR-418, Chevron 9301, 9302, Solvay Fortiflex K38-20-160
B. Novacor Chemical HD-2100, Union Carbide 2400

The Task Group agreed to make (10) joints of each of the following combinations:

UCC2400 to Phillips Marlex TR-418
UCC2400 to Chevron 9301
UCC2400 to Solvay Fortiflex K38-20-160

The joints were made at the same parameters as before with five (5) made at 475°F/100 psi (246°C/6.90 bar) interface and five (5) made at 375°F/50 psi (191°C/3.45 bar) interface. In effect, this would provide representative results for all medium density polyethylene except Uponor Aldyl A MDPE. Thus, this portion of the testing program would require 30 joints in total. It was also decided that if there were any failures with joints made under these parameters, then the fusions should be duplicated under the generic parameters 400 - 450°F/60-90 psi (204-232°C/4.14-6.21 bar).

For HDPE materials, the Task Group identified seven different high density polyethylene materials which could be classed into three main categories based on catalyst family, production process and melt index:

A. Chevron 9308, Phillips TR 480 and Solvay Fortiflex K44-15-123.
B. Novacor Chemical HD-2007-H, Chevron 9346 and UCC2480
C. Fina 3344

The HDPE cross fusion testing covered 10 joints for each of the following combinations: A to A, B to B, C to C, A to B, B to C, and A to C, for a total of 60 fusion joints. The representative materials selected from each category were the Fina 3344, UCC2480 and Phillips TR480.

For MDPE to HDPE cross fusions, the Task Group decided to use the same materials as were used for the cross fusion of 2" pipe; i.e., Fina 3344 and Union Carbide 2400. This portion of the testing program would involve A to B fusions of the two materials, for a total of 10 joints.

In addition to the tensile testing, high speed tensile impact testing, quick burst testing and 100% ultrasonic inspection, each fusion combination described in Part 3 was subjected to a long- term 176°F (80°C), 1000 hour test using 580 psi (40 bar) hoop stress. As with the 2" IPS testing, all joints passed every test conducted.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that there is a single fusion procedure with defined ranges of acceptable heater surface temperature, 400-450°F (204-232°C), and interfacial pressure, 60-90 psi (4.14-6.21 bar), for fusing most of the PE gas pipes on the market today. The PE pipes used in these tests were selected PE2406 and PE3408 materials which were deemed suitable for fuel gas applications (per ASTM D2513) and which have a grade designation, in accordance with ASTM D3350, of PE24 and PE34, respectively, excluding Uponor Aldyl A MDPE and Driscopipe D8000 HDPE. The results further indicate that there is a strong likelihood that the generic fusion procedure used in this testing (see Appendix A) could be qualified by gas pipeline operators under DOT's regulations in Part 192 for use with most of these PE gas piping products. To the extent that this PPI generic procedure in Appendix A can be qualified for use with more and more of the PE pipe products in the marketplace, the closer the industry can move to meeting DOT's objective of greater uniformity, efficiency, and simplicity in the area of fusion procedures.

ACKNOWLEDGEMENTS

This document has been produced by an industry Task Group from equipment, fitting, pipe, and resin manufacturers from the following companies.

Phillips Driscopipe
PLEXCO
CSR PolyPipe
Central Plastics
Uponor
Charter Plastics
Solvay
Fina
KWH Pipe
North American Pipe
McElroy Manufacturing
T.D. Williamson

Table 1. Overview of Polyethylene Plastic Gas Pipe Materials

Company	Resin	Melt Index (MI) Grams/10 min	High Load MI Grams/10 min.
Phillips	TR480	.11	13
Solvay	K44-15-123	.12	13
Solvay	K44-08-123	.08	8.5
Chevron	9346	.08	10
Chevron	9308	.10	10
Novacor Chem.	HD2007H	.07	8.5
Union Carbide	2480	.10	12
Fina	3344	.10	8
Phillips	TR418	.12	
Chevron	9301	.20	
Solvay	K38-20-160	.20	
Novacor Chem.	2100	.15	
Union Carbide	2400	.20	

APPENDIX A

Generic Butt Fusion Joining Procedure for PE (Polyethylene) Gas Pipe

This Appendix is intended to be used only in conjunction with PPI's Technical Report TR-33 that more fully explains the background, scope and purposes of the PPI generic procedure. This procedure has not been qualified for use with any particular piping product or combination of piping products and must be qualified for use in accordance with 49 CFR Part 192 prior to its use to join PE pipe in a gas pipeline. Any copying or reproduction of this procedure without this footnote and the accompanying TR-33 is a violation of the copyright.

This procedure is intended for PE fuel gas pipe (per ASTM D2513) which have a grade designation (in accordance with ASTM D3350) of PE24 and PE34, excluding Uponor Aldyl A MDPE and Driscopipe D8000 HDPE.

Butt Fusion Procedure Parameters:

Generic Fusion Interface Pressure Range	60-90 psi (4.14-6.21 bar)
Generic Heater Surface Temperature Range	400 - 450°F (204-232°C)

Butt Fusion Procedures:

The principle of heat fusion is to heat two surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion. When fused according to the proper procedures, the joint area becomes as strong as or stronger than the pipe itself in both tensile and pressure properties.

Field-site butt fusions may be made readily by trained operators using butt fusion machines that secure and precisely align the pipe ends for the fusion process. The six steps involved in making a butt fusion joint are:

1. Securely fasten the components to be joined
2. Face the pipe ends
3. Align the pipe profile
4. Melt the pipe interfaces
5. Join the two profiles together
6. Hold under pressure

Secure

Clean the inside and outside of the pipe to be joined by wiping with a clean lint-free cloth. Remove all foreign matter.

Clamp the components in the machine. Check alignment of the ends and adjust as needed.

Face

The pipe ends must be faced to establish clean, parallel mating surfaces. Most, if not all, equipment manufacturers have incorporated the rotating planer block design in their facers to accomplish this goal. Facing is continued until a minimal distance exists between the fixed and movable jaws of the machine and the facer is locked firmly and squarely between the jaw bushings. This operation provides for a perfectly square face, perpendicular to the pipe centerline on each pipe end and with no detectable gap.

Align

Remove any pipe chips from the facing operation and any foreign matter with a clean, untreated, lint-free cotton cloth. The pipe profiles must be rounded and aligned with each other to minimize mismatch (high-low) of the pipe walls. This can be accomplished by adjusting clamping jaws until the outside diameters of the pipe ends match. The jaws must not be loosened or the pipe may slip during fusion.

Melt

Heating tools that simultaneously heat both pipe ends are used to accomplish this operation. These heating tools are normally furnished with thermometers to measure internal heater temperature so the operator can monitor the temperature before each joint is made. However, the thermometer can be used only as a general indicator because there is some heat loss from internal to external surfaces, depending on factors such as ambient temperatures and wind conditions. A pyrometer or other surface temperature-measuring device should be used periodically to insure proper temperature of the heating tool face. Additionally, heating tools are usually equipped with suspension and alignment guides that center them on the pipe ends. The heater faces that come into contact with the pipe should be clean, oil-free and coated with a nonstick coating as recommended by the manufacturer to prevent molten plastic from sticking to the heater surfaces. Remaining molten plastic can interfere with fusion quality and must be removed according to the tool manufacturer's instructions.

Plug in the heater and bring the surface temperatures up to the temperature range (400-450°F) (204-232°C). Install the heater in the butt fusion machine and bring the pipe ends into full contact with the heater. To ensure that full and proper contact is made between the pipe ends and the heater, the initial contact should be under moderate pressure. After holding the pressure very briefly, it should be released without breaking contact. Continue to hold the components in place, without force, while a bead of molten polyethylene develops between the heater and the pipe ends. When the proper bead size is formed against the heater surfaces, the heater should be removed. The bead size is dependent on the pipe size. For 2" IPS pipe, a bead size of approximately 1/16" should be present and for 8" IPS pipe, a bead size of 1/8"- 3/16" should be present before removing the heater.

Joining

After the pipe ends have been heated for the proper time, the heater tool is removed and the molten pipe ends are brought together with sufficient force to form a double rollback bead against the pipe wall. The fusion force is determined by multiplying the interfacial pressure, 60-90 psi (4.14-6.21 bar), by the pipe area.

For manually operated fusion machines, a torque wrench can be used to accurately apply the proper force. For hydraulically operated fusion machines, the fusion force can be divided by the total effective piston area of the carriage cylinders to give a hydraulic gauge reading in psi. The gauge reading is theoretical; the internal and external drag need to be added to this figure to obtain the actual fusion pressure required by the machine.

Hold

The molten joint must be held immobile under pressure until cooled adequately to develop strength. Allowing proper times under pressure for cooling prior to removal from the clamps of the machine is important in achieving joint integrity. The fusion force should be held between the pipe ends until the surface of the bead is cool to the touch.

The pulling, installation or rough handling of the pipe should be avoided for an additional 30 minutes.

APPENDIX B

LETTERS OF ENDORSEMENT FROM PPI MEMBER COMPANIES

CHARTER PLASTICS, Inc.

221 S. Perry St.
P.O. Box 770
Titusville, PA 16354
814 827-9665
FAX 814 827-1614

LETTER OF APPROVAL
GAS PIPE BUTT FUSION PROCEDURE

Revised MAY 28, 1999

This letter is to verify that our company has conducted butt fusion testing based on the combinations shown below using the Generic Butt Fusion Parameters and Procedures shown in Appendix A of PPI Technical Report TR-33. In accordance with DOT Part 192.283 to qualify joining procedures, tensile tests per ASTM D638 and quick burst tests per ASTM D2513 were conducted on the fusion joints and the test results were shared with the manufacturers of the corresponding pipe. Based on these tests and previous testing done by a task group of PPI to validate the Generic Butt Fusion Procedure, we approve the use of the Generic Butt Fusion Parameters and Procedures in butt fusing the combinations shown below.

While procedures now specified in our company's product literature can also be used, the use of the PPI Generic Butt Fusion Joining Procedures is intended to help DOT expedite the qualification of the gas pipeline operators and add some uniformity to the industry.

Charter PE 2406 Gas --- Plexco PE 2406 Yellow
Charter PE 2406 Gas --- Uponor UAC 2000
Charter PE 2406 Gas --- Phillips 6500 Gas
Charter PE 2406 Gas --- KWH Weho Gas 2406
Charter PE 2406 Gas --- CSR Polypipe 3810
Charter PE 2406 Gas --- Ameriflow PE 2406
Charter PE 2406 Gas --- Charter PE 2406 Gas

Charter PE 2406 Gas --- Plexco PE 3408 Yellow Stripe
Charter PE 2406 Gas --- Phillips 8000 Gas
Charter PE 2406 Gas --- KWH Weho Gas 3408
Charter PE 2406 Gas --- CSR Polypipe 4810
Charter PE 2406 Gas --- Ameriflow PE 3408

Every (5) years, we will re-qualify these procedures by repeating the tests shown above. If we deviate from the particular thermoplastic piping material formulation or make any other change which is not specifically allowed by an appropriate policy in PPI Technical Report TR-3, then we will re-qualify the fusion combinations shown above.

Sincerely Yours,

Charter Plastics, Inc.

Donna Stoughton

Donna Stoughton
Dir. Sales and Marketing

♦ Visit our web site at www.charterplastics.com ♦

CSR™
PolyPipe

LETTER OF APPROVAL
GAS PIPE BUTT FUSION PROCEDURE

CSR PolyPipe™ has conducted butt fusion testing based on the combinations shown below using the Generic Butt Fusion Parameters and Procedures shown in Appendix A of PPI Technical Report TR-33. In accordance with DOT Part 192.283 to qualify joining procedures, tensile tests per ASTM D638 and quick burst tests per ASTM D2513 were conducted on the fusion joints and the test results were shared with the manufactures of the corresponding pipe. Based on these tests and previous testing done by a task group of PPI to validate the Generic Butt Fusion Procedure, we approve the use of the Generic Butt Fusion Parameters and Procedures in butt fusing the combinations shown below.

While procedures now specified in CSR PolyPipe™ product literature can also be used, the use of PPI Generic Butt Fusion Joining Procedures is intended to help DOT expedite the qualification of gas pipeline operators and add some uniformity to the industry.

CSR PolyPipe 3810---CSR PolyPipe 4810
CSR PolyPipe 3810---CSR PolyPipe 3810
CSR PolyPipe 3810---KWH Wehogas 2406
CSR PolyPipe 3810---KWH Wehogas 3408
CSR PolyPipe 3810---Charter PE 2406 Gas
CSR PolyPipe 3810---Plexco Yellowpipe
CSR PolyPipe 3810---Plexco Yellowstripe
CSR PolyPipe 3810---Driscopipe 6500
CSR PolyPipe 3810---Driscopipe 6800
CSR PolyPipe 3810---Driscopipe 8100
CSR PolyPipe 3810---Uponor UAC 2000
CSR PolyPipe 3810---Ameriflow 2406
CSR PolyPipe 3810---Ameriflow 3408

CSR PolyPipe 4810---CSR PolyPipe 4810
CSR PolyPipe 4810---KWH Wehogas 2406
CSR PolyPipe 4810---KWH Wehogas 3408
CSR PolyPipe 4810---Charter PE 2406 Gas
CSR PolyPipe 4810---Plexco Yellowpipe
CSR PolyPipe 4810---Plexco Yellowstripe
CSR PolyPipe 4810---Driscopipe 6500
CSR PolyPipe 4810---Driscopipe 6800
CSR PolyPipe 4810---Driscopipe 8100
CSR PolyPipe 4810---Uponor UAC 2000
CSR PolyPipe 4810---Ameriflow 2406
CSR PolyPipe 4810---Ameriflow 3408

These procedures should be re-qualified every five (5) years by repeating the pipe material tests shown above. If we change to a material formulation that is not based on any current formulation for the above listed products, or to a composition that has been qualified but with changes that are not allowed by an appropriate policy in PPI Technical Report TR-33, we will either: (1) re-qualify the fusion combinations, or (2) inform PPI and participating member companies that the new composition has not been qualified using the PPI Generic Butt Fusion Procedure.

Sincerely,

Monty Fisher

Monty H. Fisher
Director of Operations and Engineering

June 17, 1999

CSR PolyPipe, P.O. Box 390, Gainesville, Texas 76241-0390
Telephone: (940) 665-1721, (800) 433-5632, Facsimile: (940) 668-8612, Web site: www.csrpolypipe.com

PHILLIPS DRISCOPIPE
A DIVISION OF PHILLIPS PETROLEUM COMPANY
http://www.driscopipe.com
2929 NORTH CENTRAL EXPRESSWAY, SUITE 300
P.O. BOX 83-3866
RICHARDSON, TEXAS 75083 • 972/783-2666

July 23, 1999

Plastics Pipe Institute
1825 Connecticut Ave.,NW
Suite 680
Washington, DC 20009

Subject: PPI Generic Butt Fusion Procedures

Phillips Driscopipe verifies participation in the Plastics Pipe Institute's development of generic procedures for butt fusion joining of the polyethylene pipes specified below. Phillips Driscopipe prepared butt fusion joints of selected combinations in accordance with PPI TR-33 Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe. Phillips Driscopipe then evaluated these joints in accordance with the requirements of CFR Part 192.283 or reviewed the results of testing to these requirements that were performed by participating manufacturers. The product combinations evaluated were:

Driscopipe 6500 - Driscopipe 6500
Driscopipe 6500 - Driscopipe 6800
Driscopipe 6500 - CSR Polypipe MDPE
Driscopipe 6500 - CSR Polypipe HDPE
Driscopipe 6500 - KWH MDPE
Driscopipe 6500 - KWH HDPE
Driscopipe 6500 - Charter Plastics MDPE
Driscopipe 6500 - North American MDPE
Driscopipe 6500 - Plexco MDPE
Driscopipe 6500 - Plexco HDPE
Driscopipe 6500 - Uponor MDPE
Driscopipe 6800 - Driscopipe 6800
Driscopipe 6800 - CSR Polypipe MDPE
Driscopipe 6800 - CSR Polypipe HDPE
Driscopipe 6800 - KWH MDPE
Driscopipe 6800 - KWH HDPE
Driscopipe 6800 - Charter Plastics MDPE
Driscopipe 6800 - North American HDPE
Driscopipe 6800 - Plexco MDPE
Driscopipe 6800 - Plexco HDPE
Driscopipe 6800 - Uponor MDPE

Based on this testing and previous testing done by a PPI task group to validate the generic butt fusion procedure published as PPI TR-33, Phillips Driscopipe approves the use of the PPI Generic Fusion Parameters and Procedures when butt fusing the material combinations listed above.

Approval of the PPI Generic Butt Fusion Procedure does not replace our published procedures for joining Driscopipe products or joining Driscopipe with other manufacturers' products. Phillips Driscopipe's published butt fusion procedures may continue to be used when joining Driscopipe products.

Fusion procedures should be re-qualified on a regular basis. If Phillips Driscopipe changes the Driscopipe 6500 or Driscopipe 6800 product(s) and the change(s) require re-testing of the product(s) under PPI TR-33, Phillips Driscopipe retains the right to test the product(s) using the PPI Generic Butt Fusion Procedure or to notify PPI the product(s) have not been tested under the procedure and request removal of the product(s) from PPI TR-33. Phillips Driscopipe accepts no responsibility for changes to products by other manufactures or any possible effect on the joining to Driscopipe products using the PPI Generic Butt Fusion Procedure.

Heath W. Casteel
Technical Engineer

cc: Jim Craig (Task Group Chairman)

KWH
PIPE

Letter of Approval
Gas Pipe Butt Fusion Procedure

November 16, 1998

This letter is to verify that KWH Pipe has conducted butt fusion testing based on the combinations shown below utilizing the Generic Butt Fusion Parameters and Procedures shown in Appendix A of PPI Technical Report TR-33. In accordance with DOT Part 192.283 to qualify joining procedures, tensile tests per ASTM D638 and quick burst tests per ASTM D2513 were conducted on the fusion joints and the test results were shared with the manufacturers of the corresponding pipe. Based on these tests and previous testing done by our task group at PPI to validate the Generic Butt Fusion Procedure, we approve the use of the Generic Butt Fusion Parameters and Procedures in butt fusing the combinations shown below.

While procedures now specified in our company's product literature can also be used, the use of the Generic Butt Fusion Joining Procedures is intended to help DOT expedite the qualification of gas pipeline operators and add some uniformity to the industry.

KWH Wehogas PE2406	---	KWH Wehogas PE2406
KWH Wehogas PE2406	---	KWH Wehogas PE3408
KWH Wehogas PE2406	---	CSR PolyPipe 3810
KWH Wehogas PE2406	---	CSR PolyPipe 4810
KWH Wehogas PE2406	---	Charter MDPE 2406 Gas Pipe
KWH Wehogas PE2406	---	Plexco Yellow Gas Pipe
KWH Wehogas PE2406	---	Plexco Yellow Stripe Gas Pipe
KWH Wehogas PE2406	---	Phillips Driscopipe 6500 Gas Pipe
KWH Wehogas PE2406	---	Phillips Driscopipe 6800 Gas Pipe
KWH Wehogas PE2406	---	Uponor UAC 2000
KWH Wehogas PE2406	---	Ameriflow PE2406
KWH Wehogas PE3408	---	KWH Wehogas PE3408
KWH Wehogas PE3408	---	CSR PolyPipe 3810
KWH Wehogas PE3408	---	CSR PolyPipe 4810
KWH Wehogas PE3408	---	Charter MDPE 2406 Gas Pipe
KWH Wehogas PE3408	---	Plexco Yellow Gas Pipe
KWH Wehogas PE3408	---	Plexco Yellow Stripe Gas Pipe
KWH Wehogas PE3408	---	Phillips Driscopipe 6500 Gas Pipe
KWH Wehogas PE3408	---	Phillips Driscopipe 6800 Gas Pipe
KWH Wehogas PE3408	---	Uponor UAC 2000
KWH Wehogas PE3408	---	Ameriflow PE3408

Every five (5) years, we will re-qualify these procedures by repeating the tests shown above. If we deviate from the particular thermoplastic piping material formulation or make any other change which is not specifically allowed by an appropriate policy in PPI Technical Report TR-3, then we will re-qualify the fusion combinations shown above and notify the above manufacturers.

Sincerely

Chris J Stilwell

Chris J. Stilwell, P.Eng.
Product Engineer

CJS/fl
Att

MAIN SALES OFFICE: 16800 Devonshire Street, Suite 320, Granada Hills, CA 91344 • (818) 831-8787 • Fax (818) 831-2999 • Toll-Free (888) 4-KWHPIPE (888) 459-4747
NW SALES OFFICE: 8002 NE Highway #99, Suite 256, Vancouver, WA 98665 • (360) 695-0555 • Fax (360) 693-0623 • Toll-Free (888) 595-0055
PLANT: 742 Industrial Way, Shafter, CA 93263 • (805) 399-9327 • Fax (805) 399-9329

A member of
PPI PLASTICS PIPE INSTITUTE

AmeriFlow™
North American Pipe Corporation

Phone: (713) 840-7473
Fax: (888) 777-6404
2801 Post Oak Blvd., Suite 600
Houston, Texas 77056

Thursday, June 17, 1999

Plastics Pipe Institute
1825 Connecticut Ave.
Suite 680
Washington, DC 20009

Subject: PPI Generic Butt Fusion Procedures

This letter is to verify that our company has conducted butt fusion testing based on the combinations shown below using the Generic Butt Fusion Parameters and Procedures shown in Appendix A of PPI Technical Report TR-33. In accordance with DOT Part 192.283 to qualify joining procedures, tensile tests per ASTM D638 and quick burst tests per ASTM D2513 were conducted on the fusion joints and the test results were shared with the manufacturers of the corresponding pipe. Based on these tests and previous testing done by a task group of PPI to validate the Generic Butt Fusion Procedure, we approve the use of the Generic Fusion Parameters and Procedures in butt fusing the combinations shown below.

While procedures now specified in our company's product literature can also be used, the use of the PPI Generic Butt Fusion Joining Procedures is intended to help DOT expedite the qualifications of gas pipeline operators and add some uniformity to the industry.

Pipe Classifications tested:

AmeriFlow™PE 2406--- AmeriFlow™PE 2406
AmeriFlow™PE 2406--- Charter PE 2406
AmeriFlow™PE 2406--- Driscopipe 6500
AmeriFlow™PE 2406--- Plexco Yellow PE 2406
AmeriFlow™PE 2406--- CSR, Polypipe 3810, PE 2406
AmeriFlow™PE 2406--- KWH, Wehogas, PE2406
AmeriFlow™PE 2406--- Uponor, UAC 2000, PE 2406

AmeriFlow™PE 3408--- AmeriFlow™PE 3408
AmeriFlow™PE 3408--- CSR, Polypipe4810, PE3408
AmeriFlow™PE 3408--- Driscopipe 6800, PE 3408
AmeriFlow™PE 3408--- KWH, Wehogas, PE3408
AmeriFlow™PE 3408--- Plexco, Yellow Stripe, PE 3408

These procedures should be re-qualified every five - (5) years by repeating the tests shown above. If we change to a material formulation that is not based on any current formulation for the above listed products, or to a composition that has been qualified but with changes that are not allowed by an appropriated policy in PPI Technical Report TR-3, we will either: (1) re-qualify the fusion combinations, or (2) inform PPI and participating member companies that the new composition has not been qualified using the PPI Generic Butt Fusion Procedure.

Sincerely,
Steven W. King

AmeriFlow™
North American Pipe Corporation
Steven W. King
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Generic.wpa

Chevron

Plexco®
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Telephone: 630/350-3750 Fax: 630/350-2148

January 18, 1999

Plastics Pipe Institute
1801 K Street, NW
Suite 600K
Washington, DC 20006-1301

Subject: PPI Generic Butt Fusion Procedures for PE Gas Pipe

This letter is to verify that butt fusion testing based on the combinations shown below has been conducted using the Generic Butt Fusion Parameters and Procedures shown in Appendix A of PPI Technical Report TR-33. In accordance with DOT Part 192.283 to qualify joining procedures, tensile tests per ASTM D638 and quick burst tests per ASTM D2513 were conducted on the fusion joints and the test results were shared with the manufacturers of the corresponding pipe. Based on these tests and previous testing done by a task group of PPI to validate the Generic Butt Fusion Procedure, we concur with the use of the Generic Butt Fusion Parameters and Procedures in butt fusing the combinations shown below.

While procedures now specified in our company's product literature can also be used, the use of the PPI Generic Butt Fusion Joining Procedures is intended to help DOT expedite the qualification of gas pipeline operators and add some uniformity to the industry.

	Joined To	
Plexco Yellowpipe		Plexco Yellowpipe
Plexco Yellowstripe	"	Plexco Yellowstripe
Plexco Plexstripe II	"	Plexco Plexstripe II
Plexco Yellowpipe	"	Plexco Yellowstripe
Plexco Yellowpipe	"	Plexco Plexstripe II
Plexco Yellowstripe	"	Plexco Plexstripe II
Plexco Yellowpipe	"	CSR Polypipe 3810
Plexco Yellowstripe	"	CSR Polypipe 3810
Plexco Yellowpipe	"	CSR Polypipe 4810
Plexco Yellowstripe	"	CSR Polypipe 4810
Plexco Yellowpipe	"	Driscopipe 6500
Plexco Yellowstripe	"	Driscopipe 6500
Plexco Yellowpipe	"	Driscopipe 6800
Plexco Yellowstripe	"	Driscopipe 6800

uponor

December 1, 1998

Uponor Aldyl Company
7234 Lancaster Pike
Suite 300-A
Hockessin, DE 19707
Tel. (302) 235-4200
Fax (302) 235-4203

Letter of Approval
Gas Pipe Butt Fusion Procedure

This letter is to verify that our company has conducted butt fusion testing based on the combinations shown below using the Generic Butt Fusion Parameters and Procedures shown in Appendix A of PPI Technical Report TR-33. In accordance with DOT Part 192.283 to qualify joining procedures, tensile tests per ASTM D 638 and quick burst tests per ASTM D 2513 were conducted on the fusion joints, and the test results were shared with the manufacturers of the corresponding pipe. Based on these tests and previous testing done by a task group of PPI to validate the Generic Butt Fusion Procedure, we approve the use of the Generic Butt Fusion Parameters and Procedures in butt fusing the combinations shown below.

While procedures now specified in our company's product literature can also be used, the use of the PPI Generic Butt Fusion Joining Procedure is intended to help DOT expedite the qualification of gas pipeline operators and add some uniformity to the industry.

Uponor UAC 2000—Uponor UAC 2000
Uponor UAC 2000—Charter Gas Pipe (PE 2406)
Uponor UAC 2000—Phillips Driscopipe 6500
Uponor UAC 2000—Phillips Driscopipe 6800
Uponor UAC 2000—Plexco YELLOWPIPE
Uponor UAC 2000—Plexco YELLOWSTRIPE
Uponor UAC 2000—CSR Polypipe 3810
Uponor UAC 2000—CSR Polypipe 4810
Uponor UAC 2000—KWH WEHOGAS (PE 2406)
Uponor UAC 2000—KWH WEHOGAS (PE 3408)
Uponor UAC 2000—North American Pipe Ameriflow (PE 2406)

These procedures should be re-qualified every five (5) years by repeating the tests shown above. If we change to a material formulation that is not based on any current formulation for the above listed products, or to a composition that has been qualified but with changes that are not allowed by an appropriate policy in PPI Technical Report TR-3, we will either: (1) re-qualify the fusion combinations, or (2) inform PPI and participating member companies that the new composition has not been qualified using the PPI Generic Butt Fusion Procedure.

Sincerely,

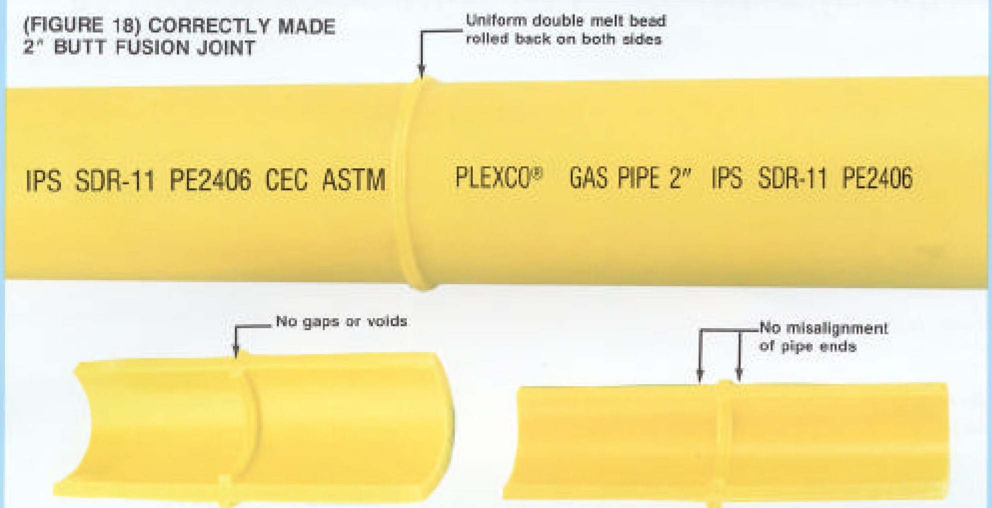
Charles M. Fischer

Charles M. Fischer
Technical Manager

APPENDIX C

PHOTOGRAPHS OF PROPERLY MADE BUTT FUSION JOINTS

(FIGURE 18) CORRECTLY MADE 2" BUTT FUSION JOINT



(FIGURE 19) CORRECT BUTT FUSION BEND TEST

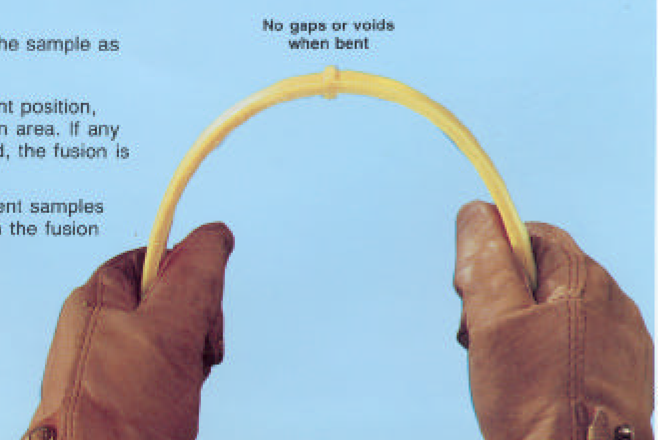
Allow the joint to cool for at least one hour before subjecting to a bend test.

Cut at least 3 strips 1" wide lengthwise through the butt fusion so that about 8" of pipe remains on each side of the joint.

Hold each strip at the ends, and bend the sample as shown in Figure 19.

Continue to hold each sample in the bent position, and thoroughly examine the entire fusion area. If any separation, cracks or voids are observed, the fusion is not satisfactory.

A joint is considered satisfactory if all bent samples are completely free of cracks or voids in the fusion area, as shown in Figure 19.



Designation: D 1598 – 02

An American National Standard

Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[1]

This standard is issued under the fixed designation D 1598; 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 test method covers the determination of the time-to-failure of both thermoplastic and reinforced thermosetting/resin pipe under constant internal pressure.

1.2 This test method provides a method of characterizing plastics in the form of pipe under the conditions prescribed.

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

1.4 *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 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[2]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[2]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass'' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[2]

D 3517 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe[2]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *failure*—any continuous loss of pressure with or without the transmission of the test fluid through the body of the specimen under test shall constitute failure. Failure may be by one or a combination of the following modes:

3.1.2 *ballooning*—any localized expansion of a pipe specimen while under internal pressure. This is sometimes referred to as ductile failure.

NOTE 1—Overall distention which results from creep caused by long-term stress is not considered to be a ballooning failure.

3.1.3 *free (unrestrained) end closure*—a pipe specimen end closure (cap) that seals the end of the pipe against loss of internal fluid and pressure, and is fastened to the pipe specimen.

3.1.4 *restrained end closure*—a pipe specimen end closure (cap) that seals the end of the specimen against loss of internal fluid and pressure, but is not fastened to the pipe specimen. Restrained end closures rely on tie-rod(s) through the pipe specimen or on external structure to resist internal pressure end thrust.

3.1.5 *rupture*—a break in the pipe wall with immediate loss of test fluid and continued loss at essentially no pressure. If rupture is not preceded by some yielding, this may be termed a non-ductile failure.

3.1.6 *seepage or weeping*—water or fluid passing through microscopic breaks in the pipe wall. A reduction in pressure will frequently enable the pipe to carry fluid without evidence of loss of the liquid.

4. Summary of Test Method

4.1 This test method consists of exposing specimens of pipe to a constant internal pressure while in a controlled environment. Such a controlled environment may be accomplished by, but is not limited to, immersing the specimens in a controlled temperature water or air bath. The time-to-failure is measured.

NOTE 2—Dimensional changes should be measured on specimens undergoing long-term strength tests. Measurements using circumferential tapes, strain gages, or mechanical extensometers provide useful information.

5. Significance and Use

5.1 The data obtained by this test method are useful for establishing stress versus failure time relationships in a controlled environment from which the hydrostatic design basis for plastic pipe materials can be computed. (Refer to Test Method D 2837 and Practice D 2992.)

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[1] This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

Current edition approved Sept. 10, 2002. Published October 2002. Originally published as D 1598 – 58 T. Last previous edition D 1598 – 97.

[2] *Annual Book of ASTM Standards*, Vol 08.04.

5.2 In order to determine how plastics will perform as pipe, it is necessary to establish the stress-failure time relationships for pipe over 2 or more logarithmic decades of time (hours) in a controlled environment. Because of the nature of the test and specimens employed, no single line can adequately represent the data, and therefore the confidence limits should be established.

NOTE 3—Some materials may exhibit a nonlinear relationship between log-stress and log-failure time, usually at short failure times. In such cases, the 10^5-hour stress value computed on the basis of short-term test data may be significantly different than the value obtained when a distribution of data points in accordance with Test Method D 2837 is evaluated. However, these data may still be useful for quality control or other applications, provided correlation with long-term data has been established.

5.3 The factors that affect creep and long-term strength behavior of plastic pipe are not completely known at this time. This procedure takes into account those factors that are known to have important influences and provides a tool for investigating others.

5.4 Creep, or nonrecoverable deformation for pipe made of some plastics, is as important as actual leakage in deciding whether or not a pipe has failed. Specimens that exhibit localized ballooning, however, may lead to erroneous interpretation of the creep results unless a method of determining creep is established that precludes such a possibility. Circumferential measurements at two or three selected positions on a specimen may not be adequate.

5.5 Great care must be used to ensure that specimens are representative of the pipe under evaluation. Departure from this assumption may introduce discrepancies as great as, if not greater than, those due to departure from details of procedure outlined in this test method.

6. Apparatus

6.1 *Constant-Temperature System*—A water bath or other fluid bath equipped so that uniform temperature is maintained throughout the bath. This may require agitation. If an air or other gaseous environment is used, provision shall be made for adequate circulation. The test may be conducted at 23°C (73°F) or other selected temperatures as required and the temperature tolerance requirements shall be ±2°C (±3.6°F).

6.2 *Pressurizing System*—Any device that is capable of continuously applying constant internal pressure on the specimen may be used. The device shall be capable of reaching the test pressure without exceeding it and of holding the pressure within the tolerance shown in 6.6 for the duration of the test.

6.3 *Pressure Gage*—A pressure gage having an accuracy sufficient to meet the pressure tolerance requirements of 6.6 is required.

6.4 *Timing Device*—A time meter connected to the pressurized fluid side of the system through a pressure or flow switch, or both. The timing device and pressure or flow switch, or both, together shall be capable of measuring the time when the specimen is at 98 % or more of test pressure with sufficient accuracy to meet the tolerance requirements of 6.6.

6.5 *Specimen End Closures*—Either free-end or restrained-end closures that will withstand the maximum test pressures may be used. Closures shall be designed so that they do not cause failure of the specimen. Free-end closures shall be used for referee tests for thermoplastic pipe.

NOTE 4—Free-end closures fasten to the specimen so that internal pressure produces longitudinal tensile stress in addition to hoop. Compared to free end closure specimens, stresses in the wall of restrained-end closure specimens act in the hoop and radial directions only. Because of this difference in loading, the equivalent hoop stress in free-end closure specimens of solid wall thermoplastic pipe are approximately 11 % lower than in restrained-end closure specimens tested at the same pressure. The test results for each specimen and the LTHS will reflect this difference in test method.

6.6 *Time and Pressure Tolerance*—When added together, the tolerance for the timing device and the tolerance for the pressure gage shall not exceed ±2 %.

7. Test Specimens

7.1 *Pipe Specimen Length*—For pipe sizes of 6 in. (150 mm) or less, the specimen length between end closures shall be not less than five times the nominal outside diameter of the pipe, but in no case less than 12 in. (300 mm). The 12 in. (300 mm) minimum specimen length requirement shall not apply to molded specimens. For larger sizes of pipe, the minimum length between end closures shall be not less than three times the nominal outside diameter but in no case less than 30 in. (760 mm).

7.2 *Measurements*—Dimensions shall be determined in accordance with Test Method D 2122 or Practice D 3567.

8. Conditioning

8.1 Specimens to be tested at 23°C shall be conditioned at test temperatures in a liquid bath for a minimum of 1 h or in a gaseous medium for a minimum of 16 h before pressurizing.

8.2 When specimens are to be tested at higher temperatures, condition them in the elevated temperature environment until they have reached test temperature.

NOTE 5—Conditioning time is a function of pipe size wall thickness, temperature differential, the film heat transfer coefficient and whether the elevated temperature environment is applied to one or both sides of the specimen. One-hour conditioning of 1-in. and smaller pipe at 82°C (180°F) in a water environment has been found to be sufficient.

8.3 Unless otherwise agreed upon, the test temperature shall be 23 ± 2°C (73 ± 3.6°F) for thermoplastics. For thermosets test at 23 ± 2°C (73 ± 3.6°F) or at maximum rated temperature depending on intended service. While every effort should be made to meet the temperature tolerances listed, temporarily exceeding the (+) temperature tolerance does not necessarily require that all samples under test be abandoned. Data points from such samples may still be acceptable. Refer also to Test Method D 2837 or Practice D 2992 to determine the suitability of these data points.

9. Procedure

9.1 Attach end closures to the pipe test sections and fill each specimen completely with the test fluid conditioned to the test temperature. Attach the specimens to the pressuring device, making certain no gas is entrapped when using liquids. Completely immerse the test specimens in the conditioning medium.

9.2 Support specimens in such a way as to prevent bending or deflection by the weight of the pipe while under test. This support shall not constrain the specimen circumferentially or longitudinally.

9.3 After conditioning the specimens as specified in Section 8, adjust the pressure to produce the desired loading. Apply the pressure to the specimens and make sure the timing devices have started.

9.4 Record the time-to-failure of each specimen. The time-to-failure shall not include periods of time during which the specimen was under depleted pressure or under no pressure.

9.4.1 Any failure occurring within one pipe diameter of the end closure shall be examined carefully. If there is any reason to believe that the failure is attributable to the end closure, the value shall be discarded in computing averages or in plotting the data.

9.4.2 The failure value of a specimen that fails due to column buckling shall be discarded in computing averages or in plotting the data.

NOTE 6—For certain materials creep measurements should be made in accordance with Test Method D 2837. It describes the procedure for determining when "circumferential expansion" must be used as a criterion for establishing the hydrostatic design stress.

9.5 *Pressure Connections*—Each specimen may be pressured individually or through a manifold system. If a manifold system is utilized, each pressure connection should include a check valve to prevent pressure depletion of the system when one specimen fails. Where the system is designed to prevent one specimen failure from depressurizing the manifold, each specimen shall have its own timing device.

9.6 *Test Fluids*—While water is normally used inside the test specimens, any fluid may be used. However, if a gas is used special care must be taken because of the potential energy stored in any compressed gas.

NOTE 7—*Test Apparatus*—All the above components with some additional features can be acquired as assembled stress rupture testers. Some units utilize a liquid bath environment that can be adjusted from −20 to +150°C. Other units offer a single pressure source with as many as 40 manifolds that can each be set for a different pressure and 240 specimen positions. A list of manufacturers of stress rupture test equipment can be obtained from the ASTM Information Center.

10. Calculation

10.1 Hoop stress in the pipe specimens is calculated using equations (approximation) for the hoop stress, as follows:

$$S = P(D - t)/2t \quad (1)$$

or

$$S = \frac{P(DR - 1)}{2} \quad (2)$$

where:

S = hoop stress, psi (MPa),
P = internal pressure, psig (MPa),
D = measured average outside diameter, in. (mm). For reinforced thermosetting pipe, outside diameter shall not include nonreinforced covers,
t = measured minimum wall thickness, in. (mm). For reinforced thermosetting pipe use minimum reinforced wall thickness, and
DR = dimension ratio, $DR = D/t$.

NOTE 8—An alternative method for calculating the hoop stress of reinforced pipe is given in the Annex of Specification D 3517.

10.2 Internal pressure in the pipe specimens is calculated using equations (approximate) for the internal pressure as follows:

$$P = \frac{2\,St}{(D - t)} \quad (3)$$

or:

$$P = \frac{2S}{(DR - 1)} \quad (4)$$

where terms are as defined in 10.1.

11. Report

11.1 The report shall include the following:

11.1.1 Complete identification of the specimens, including material type, manufacturer's name and code number, and previous history.

11.1.2 Pipe dimensions including nominal size, minimum wall thickness, average outside diameter, length of test specimen between end closures, and type of end closure. For reinforced thermosetting pipe, wall thicknesses and outside diameter shall be reinforced dimensions only. Unreinforced thicknesses shall also be reported.

11.1.3 Test temperature.

11.1.4 Test environment, including conditioning time.

11.1.5 Test fluid inside specimens.

11.1.6 Test pressure, calculated hoop stress, and time-to-failure for each specimen.

11.1.7 When pressure depletion is experienced, the time at which the pressure was depleted and time at which pressure was restored shall be reported. The failure time in this case shall be considered as the total time the specimen was under full test pressure as defined in 6.2.

11.1.8 Plot of hoop stress versus time-to-failure or computer print-out showing the stress regression line intercepts and the lower confidence limit.

11.1.9 Failure mode and any unusual effects of prolonged exposure and type of failure.

11.1.10 Date test was started and reporting date.

11.1.11 Name of test laboratory and supervisor of this test.

11.1.12 When testing assemblies identify pipe, fitting, and joint. Describe in detail the location and mode of failure.

12. Precision and Bias [3]

12.1 *Precision*—Based on a mini laboratory round-robin conducted on 2-in. medium density polyethylene pipe, the precision (one standard deviation) of this test method for medium density polyethylene pipe is as follows:

12.1.1 *Slit Failure Mode*:

12.1.1.1 Within-laboratory, ±37 % (repeatability).

12.1.1.2 Between-laboratory, ±39 % (reproducibility).

[3] Interlaboratory test data and calculations are available from ASTM Headquarters. Request RR: F 17-1037.

12.1.2 *Ductile Failure Mode*:

12.1.2.1 Within-laboratory, ±50 % (repeatability).

12.1.2.2 Between-laboratory, ±100 % (reproducibility).

12.2 *Bias*—Data obtained using this standard test method are believed to be reliable since accepted techniques of analysis are used. However, since no referee method is available, no bias statement can be made.

13. Keywords

13.1 internal pressure; plastic pipe; time-to-failure

Designation: F 1473 – 07

An American National Standard

Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins[1]

This standard is issued under the fixed designation F 1473; 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.

1. Scope

1.1 This test method determines the resistance of polyethylene materials to slow crack growth under conditions specified within.

NOTE 1—This test method is known as PENT (Pennsylvania Notch Test) test.

1.2 The test is generally performed at 80°C and at 2.4 MPa, but may also be done at temperatures below 80°C and with other stresses low enough to preclude ductile failure and thereby eventually induce brittle type of failure. Generally, polyethylenes will ultimately fail in a brittle manner by slow crack growth at 80°C if the stress is below 2.4 MPa.

1.3 The test method is for specimens cut from compression molded plaques.[2] See Appendix X1 for information relating to specimens from pipe.

1.4 *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:* [3]

D 618 Practice for Conditioning Plastics for Testing

D 1600 Terminology for Abbreviated Terms Relating to Plastics

D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

D 4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets

F 412 Terminology Relating to Plastic Piping Systems

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology F 412. Abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.1.2 *brittle failure*—a pipe failure mode which exhibits no visible (to the naked eye) permanent material deformation (stretching, elongation, or necking down) in the area of the break (Terminology F 412).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *slow crack growth*—the slow extension of the crack with time.

4. Summary of Test Method

4.1 Specimens are cut from compression molded plaques. It is precisely notched and then exposed to a constant tensile stress at elevated temperatures in air. The time for complete failure is recorded.

5. Significance and Use

5.1 This test method is useful to measure the slow crack growth resistance of molded plaques of polyethylene materials at accelerated conditions such as 80°C, 2.4-MPa stress, and with a sharp notch.

5.2 The time to failure depends on the following test parameters: temperature; stress; notch depth; and specimen geometry. Increasing temperature, stress, and notch depth decrease the time to failure. Thus, in reporting the time to failure, all the conditions of the test must be specified.

6. Apparatus

6.1 *Lever Loading Machine*, with a lever arm ratio of about 5:1. The tensile load may also be applied directly using dead weights or any other method for producing a constant load. The pull rods on the grips shall have universal action to prevent bending. The grips shall be serrated to prevent slippage. The load on the specimen shall be accurate to at least ±0.5 %.

6.2 *Furnace*, heated by ordinary incandescent light bulbs covered with aluminum foil or any other suitable heating element.

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[1] This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1997. Last previous edition approved in 2001 as F 1473 – 01 $^{\epsilon 1}$.

[2] Lu, X., and Brown, N., "A Test for Slow Crack Growth Failure in Polyethylene Under a Constant Load," *Journal of Polymer Testing*, Vol 11, pp. 309–319, 1992.

[3] 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.

6.3 *Temperature Controller*, shall be able to control the temperature within ±0.5°C with respect to the set point.

6.4 *Temperature-Measuring Device*, a thermometer or a thermocouple which can measure the temperature with an accuracy better than 0.5°C.

6.5 *Timer*, shall have an accuracy of at least 1 % and shall automatically stop when the specimen fails.

6.6 *Alignment Jig*, as shown in Fig. 1, which aligns the grips and the specimen when the specimen is being tightened in the grips. Alignment jigs which produce the same function may be used.

6.7 *Notching Machine* , for notching the specimen is shown in Fig. 2 or other machines which produce the same results may be used. The notching machine presses a razor blade into the specimen at a speed less than 0.25 mm/min. The depth of the notch is controlled within ±0.01 mm. The machine is designed so that the main notch and the side notches will be coplanar and the plane of the notching is perpendicular to the tensile axis of the specimen. The thickness of the razor blade is approximately 0.2 mm.

7. Precautions

7.1 The load shall be carefully added to avoid shocking the specimen. When the specimen is inserted in the grips, bending and twisting shall be avoided in order to prevent the premature activation of the notch. Avoid exposure to fluids such as detergents.

8. Test Specimens

8.1 Specimens are machined from a compression molded plaque of the polyethylene material.

8.2 *Specimen Geometry*—A representative geometry for compression molded plaque specimens is shown in Fig. 3.

8.3 *Dimensional Requirements*:

8.3.1 The side groove shall be 1.0 ± 0.10 mm for all plaque thicknesses.

8.3.2 The overall length is not critical except that the distance between the notch and the end of a grip should be more than 10 mm. Thicker specimens should have a greater overall length so that the gripped area will be greater in order to avoid slippage in the grip.

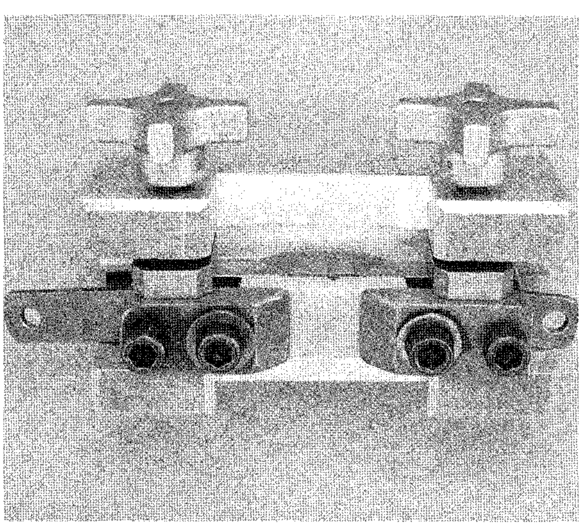


FIG. 1 Alignment Jig

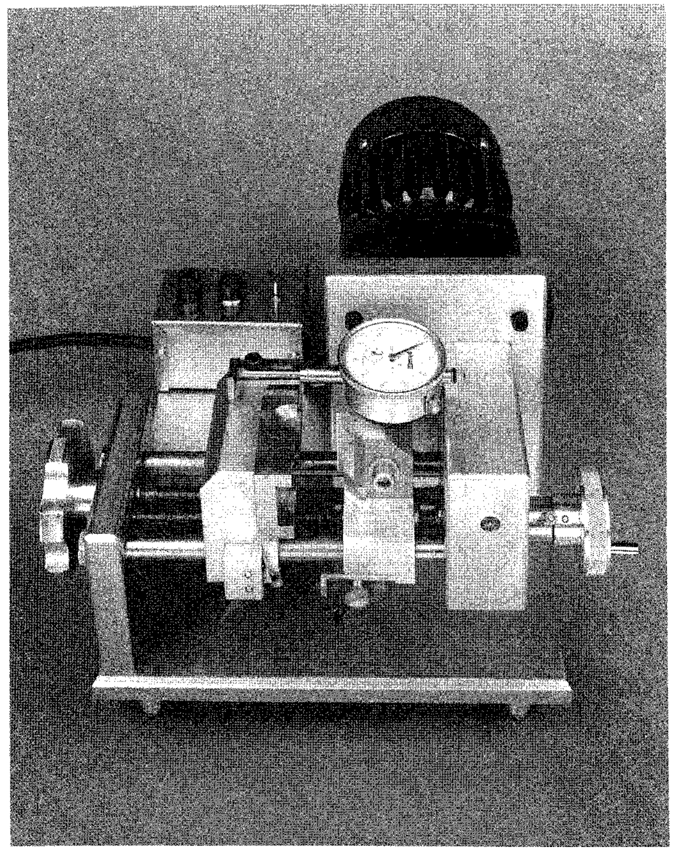
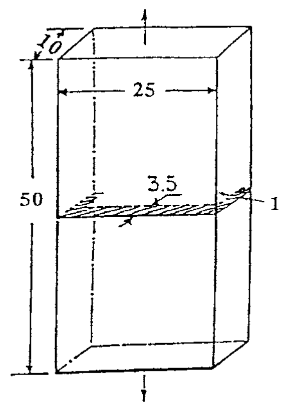


FIG. 2 Notching Machine

8.4 *Preparation of Compression Molded Plaques*—Polyethylene resins shall be evaluated by using specimens that are machined from compression molded plaques using Practice D 4703, except for the following procedures. After the resin is heated to 140 to 160°C, apply and remove the pressure three times. Increase the temperature to 170 to 190°C for 10 to 15 min without pressure. Then apply and remove the pressure three times. The specific temperatures that are used depend on the melt index of the resin, that is, a higher temperature for a lower melt index. The purpose of applying and removing the pressure is to eliminate voids. Turn off the heat and apply pressure. The time to cool between 130 and 90°C shall be greater than 80 min. Alternatively, the time to cool from the molding temperature to about room temperarture shall be greater than 5 h. During cooling the pressure is allowed to decrease naturally.

8.5 *Specimen Notching*—The specimen has two types of notches, the main notch and two side notches. The side notches are usually referred to as "side grooves." The depth requirements for these notches are given in Table 1. The main notch is produced by pressing a razor blade into the specimen at a speed of less than 0.25 mm/min. A fresh razor blade shall not be used for more than three specimens and shall be used within one day. The rate of notching for the side grooves is not important. It is important to make the side grooves coplanar with the main notch. Specimens shall be notched at room temperature.



Legend:
Arrows designate direction of tensile stress.
t = thickness.
All dimensions are in millimetres.

FIG. 3 Representative Geometry for Compression-Molded Specimen

TABLE 1 Notch Depth as a Function of Specimen Thickness[A]

This table is based on the stress intensity being the same for all thicknesses.

Thickness, mm	Notch Depth, mm
4.00	1.90
5.00	2.28
6.00	2.50
7.00	2.80
8.00	3.09
9.00	3.30
10.00	3.50
11.00	3.70
12.00	3.90
13.00	4.18
14.00	4.39
15.00	4.48
16.00	4.65
17.00	4.88
18.00	4.95
19.00	5.09
20.00	5.20

[A] For an intermediate thickness, linearly interpolate to obtain the notch depth. The notch depth in the specimen shall be within ± 0.05 mm of the interpolated value.

9. Conditioning

9.1 Unless otherwise specified, hold the test specimens for at least 1 h at the test temperature prior to loading. The length of time between notching and testing is not important.

10. Procedure

10.1 *Calculation of Test Load*:

10.1.1 Calculate the test load, *P*, as follows:

$$P = \sigma \times w \times t \tag{1}$$

where:

σ = stress,
w = specimen width, and
t = specimen thickness.

The variables *w* and *t* are based on the unnotched cross section.

10.1.2 If σ has the units of megapascals and *w* and *t* are in millimetres, and *A* is in square millimetres, then *P* has the units of Newtons. To convert Newtons to pounds, multiply by 0.225. If a lever-loaded machine is used, divide *P* by the lever arm ratio. The load on the specimen shall be ±0.5 % of the calculated load.

10.2 *Gripping the Specimen*—Using an alignment jig (Fig. 1), center the specimen in the grips so that the axis of the specimen is aligned with the grips. When the grips are tightened, it is important not to activate the notch by bending or twisting the specimen. The ends of the grips shall be at least 10 mm from the notch.

10.3 *Loading the Specimen*—When the specimen in the grips is removed from the alignment jig and transferred to the testing machine, take care that the notch is not activated by bending the specimen. Apply the load after the specimen has been held for at least 1 h at the test temperature. Apply the load gradually within a period of about 5 to 10 s without any impact on the specimen.

10.4 *Temperature Measurement*—Place the thermocouple or thermometer near the notched part of the specimen. Periodically record the temperature with a frequency that depends on the length of the test.

10.5 When the specimen fails, record the time to failure. Failure occurs when the two halves of the specimen separate completely or extensive deformation occurs in the remaining ligament.

11. Report

11.1 Compression-molded test specimens shall be identified by the polyethylene material source (resin manufacturer or other source) and lot number.

11.2 Stress based on the unnotched area.

11.3 Depth of main notch and side grooves.

11.4 Calculated load and cross-sectional dimensions of the specimen.

11.5 Test temperature.

11.6 Time to failure.

11.7 Date and time for the beginning and ending of the test.

12. Precision and Bias

12.1 *Precision*—A round robin was conducted with seven laboratories and used three resins from different producers. The standard deviation of the average values within laboratories is ±16 %. The standard deviation of the average values between laboratories is ±26 %.

12.2 *Bias*—No statement on bias can be made because there is no established reference value. The test method originated at the University of Pennsylvania. If the test results from about eight years of testing at the University of Pennsylvania can be used as reference values, then there is no bias in the results from the different laboratories with respect to the results at the University of Pennsylvania. If the test results from the University of Pennsylvania can be used as a reference, then there is no bias for the round robin starting with pellets.[4]

13. Keywords

13.1 fracture; notch testing; pipes; polyethylene; resin; slow crack growth

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: F17-1043. This report is based on a round robin of seven laboratories starting with pellets.

APPENDIX

(Nonmandatory Information)

X1. TESTING SPECIMENS FROM PIPE

X1.1 *Scope*—Test Method F 1473 has been used to measure the slow crack growth resistance of specimens from pipe.

X1.1.1 Test results are affected by size, specimen geometry, molecular orientation, and other processing effects.

X1.1.2 Extrusion generally aligns polyethylene molecules parallel to the extrusion direction. Notching perpendicular to the extrusion direction (Fig. X1.1(a)) generally gives higher results than notching parallel to the extrusion direction (Fig. X1.1(b)).

X1.1.3 Values obtained from tests of specimens cut from pipe can vary significantly from values obtained from tests of specimens machined from a compression molded plaque of the resin.

X1.2 *Significance and Use*—Test results may be useful for research, or for comparison or evaluation of resin or processing effects on slow crack growth resistance.

X1.2.1 While the resin is the primary factor in slow crack growth resistance, when tests are conducted on specimens from pipe, pipe size, pipe wall thickness, extrusion equipment, and processing can affect test results. These influences can be addressed by consistency and uniformity in preparing, loading, and notching specimens. This is especially important when testing is for the purpose of evaluation or comparison.

NOTE X1.1—Many combinations of different types of extrusion equipment, tooling, and processing conditions are used to extrude polyethylene pipe. Differences in extrusion equipment, tooling, and processing conditions are known to affect the results when specimens cut from pipe are tested in accordance with this test method.

X1.3 *Specimen Preparation:*

X1.3.1 When a section of the pipe wall is to be tested, cut sections or strips from the pipe. Sections or strips should be cut 4 to 6 mm wider than the required specimen width, then deburred, and machined to the specimen width.

X1.3.2 Fig. X1.1(a) illustrates a specimen cut from 4 in. IPS SDR 11 pipe where the load direction axis is parallel to the extrusion direction and the main notch is perpendicular to the extrusion direction. Fig. X1.1(b) illustrates a specimen from 4 in. IPS SDR 11 pipe where the load direction axis is perpendicular to the extrusion direction axis (parallel to the hoop direction) and the main notch is parallel to the extrusion direction. Fig. X1.1(c) illustrates a specimen for pipe diameters less than 25 mm.

X1.3.3 Sawing, cutting, machining, or milling operations should be carefully performed to avoid overheating the specimen.

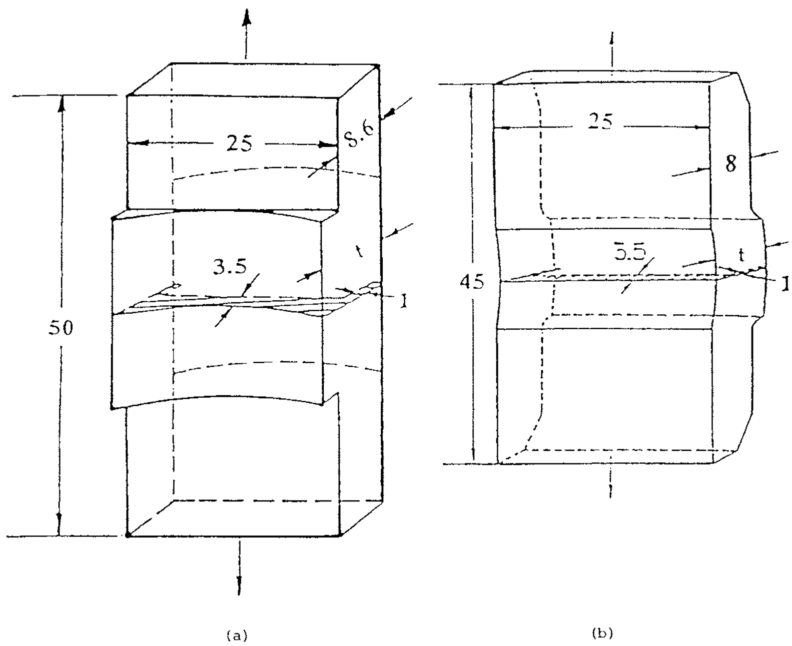
X1.3.4 *Remodeling*—Pipe may be remolded by cutting chips from the pipe, then preparing a compression molded plaque in accordance with 8.4 or by flattening a section of pipe, then heating, pressing, and cooling the flattened section in accordance with 8.4. When remolded, most extrusion processing effects will be removed, therefore, the results obtained from remolded plaques will differ from the results obtained from as-extruded pipe.

X1.4 *Specimen Dimensions:*

X1.4.1 The overall length of the specimen is not critical provided that the distance between the notch and the end of the grip should be more than 10 mm. Thicker specimens should have a greater overall length to provide sufficient grip area and to avoid slippage in the grip. The gripped area should be machined to a flat bar so that the grip does not introduce bending stresses.

X1.4.1.1 See Table X1.1 for suggested specimen width.

X1.4.1.2 Specimen thickness is typically the same as the pipe wall thickness. When wall thickness exceeds 20 mm, the side opposite the surface to be notched may be machined to 20 mm or less.



(*a*) *Longitudinal Specimen from 110-mm SDR 11 Pipe with Tensile Axis Parallel to Extrusion Direction*

(*b*) *Same as* (*a*) *With Tensile Axis Perpendicular to Extrusion Direction*

Legend:
Arrows designate direction of tensile stress.
t = wall thickness of pipe.
D = outside diameter.
All dimensions are in millimetres.

FIG. X1.1 Representative Geometries of Test Specimens

X1.4.1.3 When remolded in accordance with X1.3.4, specimen dimensions are to be in accordance with 8.2 and 8.3.

X1.4.2 *Specimen Notching*—Notch the specimen in accordance with 8.5 and Table 1. The notch is always cut perpendicular to the load application direction. See Table X1.1 for side groove depth.

NOTE X1.2—It is preferable to notch specimens so that stress intensity is a constant. Additional information on constant stress intensity and this test method is available through ASTM Headquarters. Request Research Report RR:F17-1043.[4]

X1.4.3 For specimens that are to be used in a common data set, cut the main and side notches into the same surfaces relative to the pipe outside diameter (OD) or inside diameter (ID).

X1.5 *Load Calculation*—When calculating the test load of specimens cut from pipe, $w \times t$ is not exactly the cross-sectional area of the specimen (Fig. X1.1(a)), because of the curvature, but is very close to it. For the pipe specimen (Fig. X1.1(c)), $P = \sigma A$, where A is the unnotched cross-section area of the pipe.

X1.6 *Report*—The report includes complete information on the material, specimen preparation and configuration, test parameters, results, and date performed.

X1.6.1 Report the pipe manufacturer, pipe size, pipe DR or wall thickness, pipe material, pipe resin, if available, date of manufacture, and lot number. If applicable, report the diameter and wall thickness measurements.

X1.6.2 Report how the specimen was prepared from the pipe, whether cut from pipe, or remolded from flattened pipe, or remolded from chips from pipe.

X1.6.3 Report the specimen dimensions, length, width, and thickness, and specimen machining including the machining method, and the surfaces that were machined.

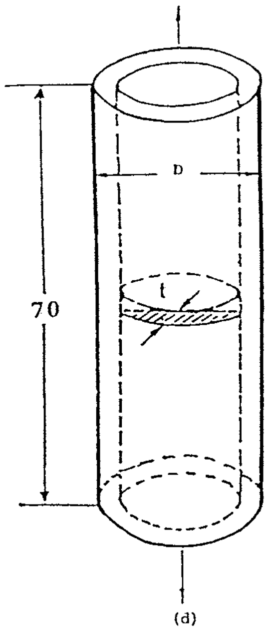
X1.6.4 Report the depths of the main and side notches, and whether oriented parallel or perpendicular to the pipe extrusion direction

X1.6.5 Report the calculated load and cross-sectional dimensions of the specimen.

X1.6.6 Report the test temperature, time to failure, and date and time for the test beginning and ending.

X1.7 *Precision and Bias:*

X1.7.1 *Precision*—A round robin was conducted with ten laboratories using three gas pipes from different producers. For specimens from pipe that were prepared alike, the standard deviation of the test results within laboratories is less than ± 15 %, and the standard deviation of the average values from the different laboratories is less than ± 17 %. With a confidence level of 95 %, it is concluded that the precision of within laboratory and between laboratory are not significantly different when specimens from pipe are prepared alike. A research



(*d*) *Specimen for C Less Than 25 mm; Notch Depth is Equal to Wall Thickness*

Legend:
Arrows designate direction of tensile stress.
t = wall thickness of pipe.
D = outside diameter..
All dimensions are in millimetres.

FIG. X1.1 Representative Geometries of Test Specimens *(continued)*

TABLE X1.1 Suggested Dimensions for Specimens Cut from Pipe

Pipe Outside Diameter[A]	Specimen Width, mm	Side Groove Depth, mm
<25 mm (<¾ in. IPS)	[B]	none[B]
25 to <90 mm (¾ in. IPS to <3 in. IPS)	15 ± 2	0.50± 0.10
90 to <115 mm (3 in. IPS to <4 in. IPS)	20 ± 2	0.50 ± 0.10
115 mm and larger (4 in. IPS & larger)	25 ± 2	1.00 ± 0.10

[A]Approximate IPS range.
[B]Same as pipe outside diameter. See Fig. X1.1(c).

report on file at ASTM Headquarters[5] provides information on a round robin of ten laboratories using three pipes from different producers.

X1.7.2 *Bias*—No statement on bias can be made because there is no established reference value for specimens from pipe. The test method originated at the University of Pennsylvania. If test results from about eight years of testing at the University of Pennsylvania can be used as reference values, then there is no bias in the results from the different laboratories with respect to the results at the University of Pennsylvania. If the test results from the University of Pennsylvania can be used as a reference, then there is no bias for the round robin starting with pipes.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: RR: F17-1041.

ASTM Research Report

File No. F17-1043 **Date:** November 30, 1996

Title: Supporting Data for ASTM F1473, Test for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins

Designation No.: F1473

Author: Norman Brown

Sponsoring Subcommittee: F17.40

Submitted by: Norman Brown

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Research Reports are filed in and available from the Information Center at ASTM Headquarters. The Research Report file provides a place for orderly storage and retrieval of data derived from the extensive research carried out in, or sponsored by, the technical committes.

A Research Report Format Guide for developing a research report is available from ASTM Headquarters.

Research Reports are transmitted to Headquarters by the sponsoring committee.

cc: Main Committee Chairman
Main Committee Secretary
Subcommittee Chairman
Staff Manager
Editor

ASTM
100 Barr Harbor Dr.
West Conshohocken, PA 19428-2959

ASTM Research Report November 30,1996

Title: Supporting Data for F 1473, Notch tensile test on compression molded pellets to measure the resistance to slow crack growth

Author: Norman Brown

Subcommittee F17.40

Submitted by: Norman Brown

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NOV 18 1996
A.S.T.M.

Round Robin Participants

Union Carbide

CSR Polypipe

Phillips

Solvay

Novacor

Chevron

University of Pennsylvania

Round Robin Protocol April 26,1996

10 test specimens

Plaque thickness 10 mm.

Notch depth 3.50 mm. If specimen thickness is not within 10 +-0.1 mm adjust notch depth in accordance with Table 1 in F1473

Side notches(side grooves) 1.00 mm deep

Width of specimen approximately 25 +-1mm

Temperature- 80+-0.5°C

Stress- 2.4 MPa based on unotched cross section area

Smooth sides of specimen near the notch in order to get a good measurement of the width.

Place some insulation around edge of mold during cooling.

Do not cool plaque faster than rates in F1473

Report

1. Thickness of specimen
2. Width of specimen
3. Load
4. Temperature
5. Failure time
6. Reason for rejecting data
7. Location of specimen if taken from more than one plaque

PENT Test Round Robin Results on Three Resins

Company	Average	Lifetime	(Hour)	Standard	Deviation	(Hour)	%	Standard	Deviation
	RA/n	RB/n	RC/n	RA	RB	RC	RA	RB	RC
A	19.1/10	47.3/10	2.8/7	3.9	7.9	0.6	20	17	21
B	20.1/10	55.0/9	2.6/9	3.0	7.7	0.5	15	14	19
C	29.6/8		3.4/2	7.3		0.2	25		5
D	21.0/17			2.1			10		
E	17.7/10	49.7/10	2.6/10	2.6	2.0	0.9	15	4	35
F	18.3/10	51.5/20	4.5/10	1.1	3.8	0.4	6	7	8
G	28.8/9	72.0/8	4.0/10	4.4	8.5	0.5	15	12	12
Averages	22./±5.0	55./±9.9	3.3/±0.8	3.5	6.0	0.5	15	10.8	17

	RA	RB	RC	Average
Within Laboratory Precision (%)	18	12	18	16
Between Laboratory Precision (%)	27	21	30	26

Precision Analysis

	Resin Designation		
	RA	RB	RC
No. labs (P)	7	6	6
Av. tests/lab (n)	11	11	9.5
Cell Av. ($\ddot{x}$)			
Std. Dev. of cell (S)			
Av. of cell averages ($\dot{x}$)	22.0	55.1	3.3
Std Dev of cell averages (S $\ddot{x}$)	5.0	9.9	0.8
Repeatability ($Sr=\sqrt{\sum S^2/P}$)	4.0	6.5	0.6
Reproducability (SR) larger of SR or $\sqrt{(S\overline{x})^2 + S^2r(n-1)/n}$	6.3	11.6	1.0
Within lab precision ($Sr/\dot{x}$) %	18	11.8	18
Between lab precision ($SR/\dot{x}$) %	27	21.2	30

Av within lab precision	16%
Av between lab precision	26%

Bias Analysis

Bias is calculated relative to University of Pennsylvania average value.

U of Penn	18.3	51.5	4.5
$\dot{x}$	22.0	55.1	3.3
Bias ($xp-\dot{x}$)/xp %	20	7	27

Av Bias = 18% which is less than the "Av between lab precision" = 26%

In this round robin the protocol had each laboratory start with pellets. In the previous one, it started with pipes.

A

ASTM F1473 ROUND ROBIN
COMPRESSION MOLDED DATA

DETERMINATION NUMBER	SAMPLE RA PENT HRS.	SAMPLE RB PENT HRS.	SAMPLE RC PENT HRS.
1	17.2	42	2.6
2	21.4	51.5	2.5
3	25.8	52.3	2.7
4	19.6	65.8	2.0
5	19.7	40.9	3.1
6	12.7	39.3	2.9
7	19.6	48.1	3.8
8	16.8	41.6	
9	15.1	47.8	
10	23.4	43.4	
Avg.	19.1	47.3	2.8
Std. Dev.	3.9	7.9	0.6
Variability	20%	17%	21%

Date: 9/17/96

B

LTR. NO. 167
SHEET 3 of 7

TEST DATA (RA)

DATE PLACED ON TEST	STATION / SAMPLE NO.	COMPLETE PRINT LINE	TEST PRESSURE	TEST TEMP	PASS / FAIL	HOURS ON LINE	TECH INT.
06-25-96	2 / 2	N/A	30.5PSI	80C	N/A	23.5	LRT
06-25-96	3 / 3	N/A	31.5PSI	80C	N/A	21.3	LRT
06-25-96	4 / 4	N/A	30.9PSI	80C	N/A	20.9	LRT
06-25-96	5 / 5	N/A	31.0PSI	80C	N/A	19.1	LRT
06-25-96	6 / 6	N/A	31.2PSI	80C	N/A	16.2	LRT
06-25-96	8 / 8	N/A	29.8PSI	80C	N/A	25.9	LRT
06-25-96	9 / 9	N/A	30.3PSI	80C	N/A	17.2	LRT
06-25-96	10 / 10	N/A	30.6PSI	80C	N/A	18.4	LRT
06-25-96	11 / 11	N/A	29.9PSI	80C	N/A	20.2	LRT
06-25-96	12 / 12	N/A	30.6PSI	80C	N/A	18.2	LRT

$\bar{x} = 20.1$
$s = 3.0$
15%

$\bar{x} = 20.1$
$s = 3.0$
15%

B

LTR. NO. 167
SHEET 5 of 7

TEST DATA (RB)

DATE PLACED ON TEST	STATION / SAMPLE NO.	COMPLETE PRINT LINE	TEST PRESSURE	TEST TEMP	PASS / FAIL	HOURS ON LINE	TECH INT.
6-10-96	2 / 2	N/A	31.6PSI	80C	N/A	51.6	LRT
6-10-96	3 / 3	N/A	31.1PSI	80C	N/A	70.6	LRT
6-10-96	4 / 4	N/A	31.3PSI	80C	N/A	188.3 X	LRT
6-10-96	5 / 5	N/A	31.3PSI	80C	N/A	47.8	LRT
6-10-96	6 / 6	N/A	31.4PSI	80C	N/A	52.8	LRT
6-10-96	8 / 8	N/A	33.3PSI	80C	N/A	47.1	LRT
6-10-96	9 / 9	N/A	31.2PSI	80C	N/A	48.2	LRT
6-10-96	10 / 10	N/A	31.4PSI	80C	N/A	57.5	LRT
6-10-96	11 / 11	N/A	31.0PSI	80C	N/A	57.6	LRT
6-10-96	12 / 12	N/A	31.9PSI	80C	N/A	61.6	LRT

$$\frac{188-55}{7.7} = \frac{133}{7.7} = 17.30$$

55.0
7.7
100%

LTR. NO. 167
SHEET 2 of 2

B

TEST DATA (RC)

DATE PLACED ON TEST	STATION / SAMPLE NO.	COMPLETE PRINT LINE	TEST PRESSURE	TEST TEMP	PASS / FAIL	HOURS ON LINE	TECH INT.
06-19-96	2 / 2	N/A	29.8PSI	80C	N/A	3.2	LRT
06-19-96	3 / 3	N/A	30.5PSI	80C	N/A	2.5	LRT
06-19-96	4 / 4	N/A	32.1 PSI	80C	N/A	2.5	LRT
06-19-96	5 / 5	N/A	30.1PSI	80C	N/A	2.1	LRT
06-19-96	6 / 6	N/A	30.5PSI	80C	N/A	3.5	LRT
06-19-96	8 / 8	N/A	30.9PSI	80C	N/A	15.5	LRT
06-19-96	9 / 9	N/A	31.4PSI	80C	N/A	2.9	LRT
06-19-96	10 / 10	N/A	31.7PSI	80C	N/A	2.0	LRT
06-19-96	11 / 11	N/A	30.0PSI	80C	N/A	2.1	LRT
06-19-96	12 / 12	N/A	30.0PSI	80C	[illegible]	2.6	LRT

X

2.6
0.5
19.0

THE TESTING OF THE ABOVE SAMPLES HAS BEEN COMPLETED.

TEST [illegible]TA \ TEST PARAMETERS

C

LOCATION: NTC
PAGE 1 OF 1

LABORATORY: Pipe Test
DATE OF ISSUE: January 25, 1993
REVISION NO: [illegible]
REVISION DATE: [illegible] 14, 1993

PENT TEST SAMPLE PREPA[illegible]ON DATA SHEET

RESIN CODE: [illegible]
SDK: Plasene sample
DATE ON: May [illegible]/96
LOT: Sample RA
AVG. O.D.: [illegible] inches
LOG #: 96-1399
OTHER: temperature 80C ±0.5 C
ENTERED [illegible]

PREP #	POSITION	WIDTH (mm)	THICKNESS (mm)	NOTCH DEPTH (mm)	LEVER WEIGHT (g)	FAILURE TIME (min)	HOURS FAIL[illegible]	
1	1	24.43	9.06	3.5mm front	10843		21.[illegible]	
2	2	24.00	9.46	1.0mm sides	11122		3[illegible]	
3	1	24.56	9.64		11598		[illegible]	
4	2	24.21	9.51		11279		[illegible]	
5	1	23.81	9.56		11151		31.9	
6	2	24.06	9.51		11209		25.8	
7	1	24.17	9.40		11130		35.9	
8	2	24.06	9.55		11256		21.2	x̄ = 29.6 hrs
9	1	24.47	9.55		11448			sd = 7.3 hrs.
10	2	24.14	[illegible]		11235			[illegible]
Average		[illegible].19	[illegible]					

R202.1

TEST DATA \ TEST PARAMETERS

C

LOCATION: NTC
PAGE 1 OF 1

LABORATORY: Pipe Test
DATE OF ISSUE: January 25, 1993
REVISION NO: 02
REVISION DATE: June 14, 1993

PENT TEST SAMPLE PREPARATION DATA SHEET

[illegible]: [illegible]
LOT: Sample RB
LOG #: 96-1400

SDR: [illegible]
AVG. O.D.: [illegible] inches
OTHER: Temperature 80°C ± 0.5°C

DATE ON: June 24/96
T.S. REP: ____ TECH: [illegible]
ENTERED LASU: YES [illegible]

PREP #	POSITION	WIDTH (mm)	THICKNESS (mm)	NOTCH DEPTH (mm)	LEVER WEIGHT (g)	FAILURE TIME (min)	HOURS TO FAILURE	TYPE OF FAILURE
1	1	24.67	9.18		11094	92.3 hrs		
2	2	24.24	9.31		11055	57.7 hrs		
3	1	24.56	9.21		11249	87.6 hrs		
4	2	24.10	9.28		10954	102.7 hrs		
5	1	24.31	9.24		11004	96.8 hrs		
6	2	24.47	9.29		11136	109.2 hrs		
7							average of 6 data pts	
8							= 91.1 hrs	
							sd = 18.0	
							[illegible]	

TEST DATA / TEST PARAMETERS

C

LABORATORY: Pipe Test
DATE OF ISSUE: January 25, 1993
REVISION NO.: 02
REVISION DATE: June 14, 1993

PAGE: 1 OF 1

PENT TEST SAMPLE PREPARATION DATA SHEET

RESIN CODE: Round Robin
LOT: Sample C
LOG #: 96-1804

[illegible]	POSITION	WIDTH (mm)	THICKNESS (mm)	NOTCH DEPTH (mm)	LEVER WEIGHT (g)	FAILURE TIME (hrs)	[illegible]	
	1	25.37	12.57	3.5 mm Center 10 mm sides	15371	72.5		Ductile
	2	25.20	12.24		15110	68.5		
	1	25.89	12.40		14512	40.4		
	2	25.18	12.46		15370	92.3	x̄ = 61.1 hrs	
	1	24.80	12.57		15291	42.7	Dev. = 17 hrs	
	1	23.70	12.46		14946	59.5		
	2	24.00	12.44		14626	62.1		
	2	23.91	12.02		14133	57.1		
Latest	1	24.27	12.08	8.9 mm (S) 9.0 mm (S)	14327	3.22		Brittle
Latest	2	25.01	12.8	4.05 mm (C) 1.0 mm (S)	15374	3.52		Brittle

Oct 15, 1996
Latest Data

D

Results on RA resin

Author:
Date: [illegible]

Listed below are the currently available results of the PENT Round Robin on black PE resin supplied by Solvay. Results are from a pair of specimens machined from a single slab. Each slab was molded separately directly from pellets. Results are in hours to failure.

21.4	-	22.0
26.1	-	17.1
21.0	-	20.4
24.3	-	No Result (Operator Error)
19.2	-	19.6
19.4	-	23.4
18.5	-	23.3
22.3	-	24.5
24.3	-	19.0
19.9	-	20.9
21.2	-	20.7
19.0	-	20.1
22.2	-	23.2
19.5	-	20.4
18.8	-	21.5
22.1	-	18.3
20.8	-	18.4

20.99 = Av.
2.08 Std. Dev.

E

PENT TESTING

TEST CONDITIONS: 80°C & 2.4 MPa.

TEST SPECIMENS

PIPE SECTIONS: SEE ASTM F1473 - 94 FOR SPECIMEN REQUIREMENTS.

COMPRESSION MOLDED PLAQUES: 3.50mm MAIN NOTCH & 1.0mm SIDE NOTCHES, SLOWLY COOLED THEN MILLED TO SPECS.

Resin	Specimen ID	Specimen Type	Specimen Thickness mm	Specimen Width mm	Calculated Load lbs	Start Date	End Date	Lifetime hrs	Comments
RA	19220-46-2	PLAQUE	10.033	25.37	137.450	7/1/96	7/1/96	20.1	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	10.058	25.56	138.825	7/1/96	7/1/96	15.3	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	10.033	25.17	136.367	7/1/96	7/1/96	16.1	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.550	25.48	131.400	7/1/96	7/1/96	17.6	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.576	25.53	132.017	7/1/96	7/1/96	19.8	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.855	25.54	135.916	7/1/96	7/1/96	15.3	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.550	25.28	130.369	7/1/96	7/1/96	16.2	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.627	25.52	132.668	7/1/96	7/1/96	20.6	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.550	25.30	130.472	7/1/96	7/1/96	14.5	ROUND ROBIN TEST
RA	19220-46-2	PLAQUE	9.601	25.53	132.361	7/1/96	7/1/96	21.6	**Ave = 17.7 + 2.6**
RB	19220-46-3	PLAQUE	9.576	25.38	131.241	7/1/96	7/3/96	51.8	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.576	25.29	130.776	7/1/96	7/3/96	49.5	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.652	25.41	132.439	7/1/96	7/3/96	48.2	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.677	25.40	132.730	7/1/96	7/2/96	47.3	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.550	25.47	131.349	7/2/96	7/4/96	48.9	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.601	25.41	131.739	7/2/96	7/4/96	49.1	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.703	25.40	133.086	7/2/96	7/4/96	49.0	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.703	25.44	133.296	7/2/96	7/3/96	47.9	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.576	25.48	131.758	7/2/96	7/4/96	53.5	ROUND ROBIN TEST
RB	19220-46-3	PLAQUE	9.677	25.47	133.096	7/2/96	7/4/96	52.1	**Ave = 49.7 + 2.0**
RC	19220-46-4	PLAQUE	9.779	25.35	133.865	7/2/96	7/2/96	2.2	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.843	25.20	133.944	7/2/96	7/2/96	2.3	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.804	25.36	134.260	7/2/96	7/2/96	2.1	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.703	25.28	132.458	7/2/96	7/2/96	2.3	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.855	25.34	134.852	7/3/96	7/3/96	2.2	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.855	25.23	134.266	7/3/96	7/3/96	1.9	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.728	25.23	132.536	7/3/96	7/3/96	2.5	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.779	25.17	132.914	7/3/96	7/3/96	1.9	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.906	25.23	134.961	7/3/96	7/3/96	3.6	ROUND ROBIN TEST
RC	19220-46-4	PLAQUE	9.779	25.23	133.231	7/3/96	7/3/96	4.7 ?	**Ave = 2.6 + 0.9**

$\frac{4.7 - 2.6}{.9}$ $\frac{2.1}{.9} = 2.3$ SD

F

Resin RA

Sample	Failure Time/Minutes
1	1075
2	1191
3	1071
4	1153
5	1198
6	1123
7	1094
8	1027
9	1070
10	994

Average = 1100 min = 18.3 hr.
Std. Dev. = 66.8 = 1.1 hr.
%SD = 6%

F

Resin RB

Sample	Failure Time/Minutes
1	2807
2	2859
3	3349
4	3001
5	2660
6	3062
7	3228
8	3198
9	3416
10	3185
11	2681
12	3104
13	3108
14	3334
15	2934
16	3134
17	2863
18	3268
19	3180
20	3442

Average = 3091.6 min
Std. Dev. = 230.4
% SD = 7.5%

Average specimen thickness = 10.15mm; SD = 0.03mm

F

Resin RC

Sample	Failure Time/Minutes
1	242
2	287
3	256
4	258
5	238
6	265
7	252
8	285
9	302
10	287

Average = 268 min
Std. Dev. = 23 min.
% SD = 8.6%

G Prepa 19/96 09:51 80°C

PENT #	SAMPLE	RUN/SPEC#	LOT	DATE	STATION	T(MM)	W(MM)	GRAMS	HOURS	COMMENTS
P55	RA	1	BLACK	4JUN96	11	9.90	25.03	11,968	26.5	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	2	BLACK	4JUN96	12	10.10	25.03	12,223	28.8	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	3	BLACK	4JUN96	13	9.89	25.02	11,960	39.2	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	4	BLACK	4JUN96	14	9.89	25.03	11,965	24.8	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	5	BLACK	4JUN96	15	10.03	25.04	12,151	28.9	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	6	BLACK	4JUN96	16	9.92	25.06	12,016	26.9	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	7	BLACK	12JUN96	18	9.75	25.03	11,776	31.8	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	8	BLACK	12JUN96	19	9.74	25.06	11,778	27.8	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	9	BLACK	12JUN96	20	9.98	25.03	12,084	24.9	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RA	10	BLACK	X	X	X	X	X	X	ERROR IN SAMPLE PREPARATION
	RA AVERAGE								28.8	RA (AVERAGE OF 9 TESTED) 5.4 SD
P55	RB	1	NATURAL	30MAY96	9	10.01	24.84	12,028	74.1	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	2	NATURAL	30MAY96	10	9.61	24.43	11,348	118.3 X	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	3	NATURAL	30MAY96	11	10.12	25.13	12,287	84.1	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	4	NATURAL	30MAY96	12	9.78	24.88	11,758	77.2	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	5	NATURAL	30MAY96	13	10.09	25.02	12,205	78.3	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	6	NATURAL	30MAY96	14	10.10	25.05	12,232	67.4	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	7	NATURAL	30MAY96	15	10.09	25.07	12,239	69.1	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	8	NATURAL	30MAY96	16	10.11	25.05	12,245	56.3	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	9	NATURAL	4JUN96	6	9.93	24.53	11,779	25.9 X	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RB	10	NATURAL	4JUN96	9	10.10	25.09	12,261	69.4	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
	RB AVERAGE								72.0	RB (AVERAGE OF 10 TESTED) SD = 8.5 > 5.4 SD
P55	RC	1	NATURAL	18JUN96	11	10.04	25.07	12,159	4.4	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	2	NATURAL	18JUN96	12	10.03	25.04	12,142	4.1	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	3	NATURAL	18JUN96	13	10.01	25.10	12,146	4.7	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	4	NATURAL	18JUN96	14	10.03	25.02	12,132	3.5	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	5	NATURAL	18JUN96	15	10.02	25.04	12,138	3.7	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	6	NATURAL	18JUN96	16	10.01	25.08	12,137	4.2	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	7	NATURAL	18JUN96	17	10.01	25.05	12,122	3.6	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	8	NATURAL	18JUN96	18	10.02	25.07	12,126	4.0	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	9	NATURAL	18JUN96	19	10.01	25.08	12,119	4.6	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
P55	RC	10	NATURAL	18JUN96	20	10.03	25.06	12,160	3.4	LOCATION OF SPECIMENS: FROM AROUND PERIMETER OF 6" X 6" PLAQUE.
	RC AVERAGE								4.0	RC (AVERAGE OF 10 TESTED)

√39.2
10.4
4.4
118.3
48.3
8.5
72
8.5
4.0
0.5
10%

Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings[1]

This standard is issued under the fixed designation D 2657; 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 practice describes general procedures for making joints with polyolefin pipe and fittings by means of heat fusion joining techniques in either a shop or field environment. These procedures are general ones. Specific instructions for heat fusion joining are obtained from product manufacturers.

1.2 The techniques covered are applicable only to joining polyolefin pipe and fittings of related polymer chemistry, for example, polyethylenes to polyethylenes, polypropylenes to polypropylenes, or polybutylenes to polybutylenes. Material, density, and flow rate shall be taken into consideration in order to develop uniform melt viscosities and formation of a good fusion bond when joining the same material to itself or to other materials of related polymer chemistry.

1.3 Parts that are within the dimensional tolerances given in present ASTM specifications are required to produce sound joints between polyolefin pipe and fittings when using the joining techniques described in this practice.

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

1.5 The text of this practice references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the practice.

1.6 *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.* See specific safety precautions in 3.1.1, 5.2, 8.2.3.1, Note 8 and Note 9, and A1.1.

2. Referenced Documents

2.1 *ASTM Standards:*

F 905 Practice for Qualification of Polyethylene Saddle Fusion Joints[2]

F 1056 Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings[2]

2.2 *PPI Documents*[3]

TR-33 Generic Butt Fusion Joining for Polyethlene Gas Pipe

3. Summary of Practice

3.1 Heat-fusion joining uses a combination of heat and force resulting in two melted surfaces flowing together to produce a joint. Fusion bonding occurs when the joint cools below the melt temperature of the material. There is a temperature range within which any particular material is satisfactorily joined. The specific temperature used requires consideration of the properties of the specific material, and the joining environment. With Techniques II or III (3.3.2 or 3.3.3), there is also an appropriate force to be applied which depends upon the material, the fusion equipment being used, and fusion temperature.

3.1.1 Electrically powered heat fusion tools and equipment are usually not explosion proof. When performing heat fusion in a potentially combustible atmosphere such as in an excavation where gas is present, all electrically powered tools and equipment that will be used in the combustible atmosphere shall be disconnected from the electrical power source and operated manually to prevent explosion and fire. For the heating tool, this requires bringing the heating tool up to or slightly above temperature in a safe area, then disconnecting it from electrical power immediately before use. This procedure is limited to smaller sizes where heating is accomplished before the heating tool drops below acceptable temperature.

3.2 Adequate joint strength for testing is attained when all of the joint material cools to ambient temperature. The joint shall not be disturbed or moved until it has cooled.

NOTE 1—Polybutylene undergoes a crystalline transformation for several days after cooling below its melt temperature. Although this phenomenon has an effect on the ultimate physical properties of the material, its effect on testing of joints has not been found to be significant. If there is any question of its effect, a comparison should be made between joints that have been conditioned for different periods of time in order to establish the conditioning-time relationship.

[1] This practice is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

Current edition approved Aug. 10, 2003. Published November 2003. Originally approved in 1967. Last previous edition approved in 1997 as D 2657 – 97.

[2] *Annual Book of ASTM Standards*, Vol 08.04.

[3] Plastic Pipe Insititue Inc., 1825 Connecticut Ave., NW Suite 680 Washington, DC 20009.

3.3 Three fusion techniques are covered in this practice as follows:

3.3.1 *Procedure 1, Socket Fusion*—The socket-fusion technique involves simultaneously heating the outside surface of a pipe end and the inside of a fitting socket, which is sized to be smaller than the smallest outside diameter of the pipe. After the proper melt has been generated at each face to be mated, the two components are joined by inserting one component into the other. See Fig. 1. The fusion bond is formed at the interface resulting from the interference fit. The melts from the two components flow together and fuse as the joint cools. Optional alignment devices are used to hold the pipe and socket fitting in Logitudinal alignment during the joining process; especially with pipe sizes 3 in. IPS (89 mm) and larger.

3.3.2 *Procedure 2, Butt Fusion*—The butt-fusion technique in its simplest form consists of heating the squared ends of two pipes, a pipe and a fitting, or two fittings, by holding them against a heated plate, removing the plate when the proper melt is obtained, promptly bringing the ends together, and allowing the joint to cool while maintaining the appropriate applied force. See Fig. 2. An alignment jig shall be used to obtain and maintain suitable alignment of the ends during the fusion operation.

3.3.3 *Procedure 3, Saddle Fusion*—The saddle-fusion technique involves melting the concave surface of the base of a saddle fitting, while simultaneously melting a matching pattern on the surface of the pipe, bringing the two melted surfaces together and allowing the joint to cool while maintaining the appropriate applied force. See Fig. 3.

4. Significance and Use

4.1 The procedures described in Sections 7, 8, and 9, when implemented using suitable equipment and procedures in either a shop or field environment, produce strong pressure-tight joints equal to the strength of the piping material. Some materials are more adaptable to one technique than another. Melt characteristics, average molecular weight and molecular weight distribution are influential factors in establishing suitable fusion parameters; therefore, consider the manufacturer's instructions in the use or development of a specific fusion procedure.

5. Operator Experience

5.1 Skill and knowledge on the part of the operator are required to obtain a good quality joint. This skill and knowledge is obtained by making joints in accordance with proven procedures under the guidance of skilled operators. Evaluate operator proficiency by testing sample joints.

5.2 The party responsible for the joining of polyolefin pipe and fittings shall ensure that detailed procedures developed in conjunction with applicable codes and regulations and the manufacturers of the pipe, fittings, and joining equipment involved, including the safety precautions to be followed, are issued before actual joining operations begin.

6. Apparatus: General Recommendations

6.1 *Heating Tool*—The tool may be heated by gas or electricity. Gas-fired heaters for 2in. IPS and smaller socket and butt fusion joints only, shall have heat sinks of sufficient capacity to prevent excessive draw down of the tool temperature, and are used only in above-freezing conditions. Electric heating plates maintain consistent fusion temperatures when provided with an adequate power source. Electric heating plates for general fusion use shall be controlled thermostatically and most are adjustable for a set point temperature ranging from 300 to 575°F (150 to 300°C). Some tools may have a fixed set point for a particular application.

6.2 *Heating Tool Faces*—Heating tools may be made from materials such as aluminum, stainless steel, copper, or copper alloys. Copper or copper-alloy heating faces are not suitable,

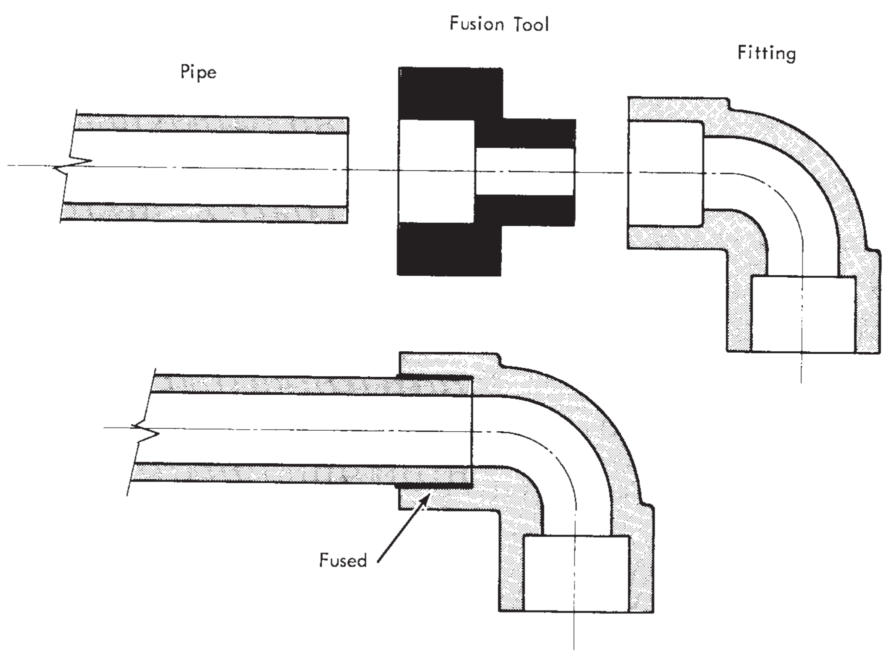

FIG. 1 Socket Fusion

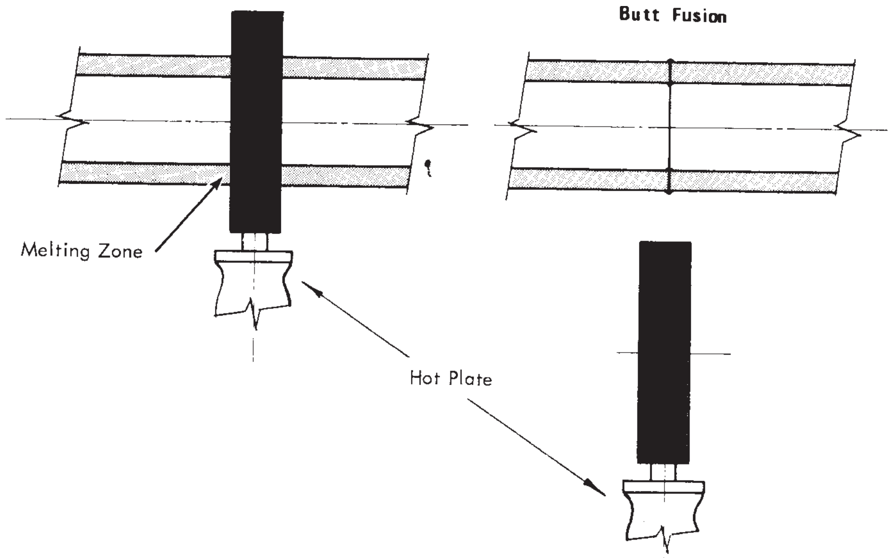

FIG. 2 Typical Butt Fusion Operation

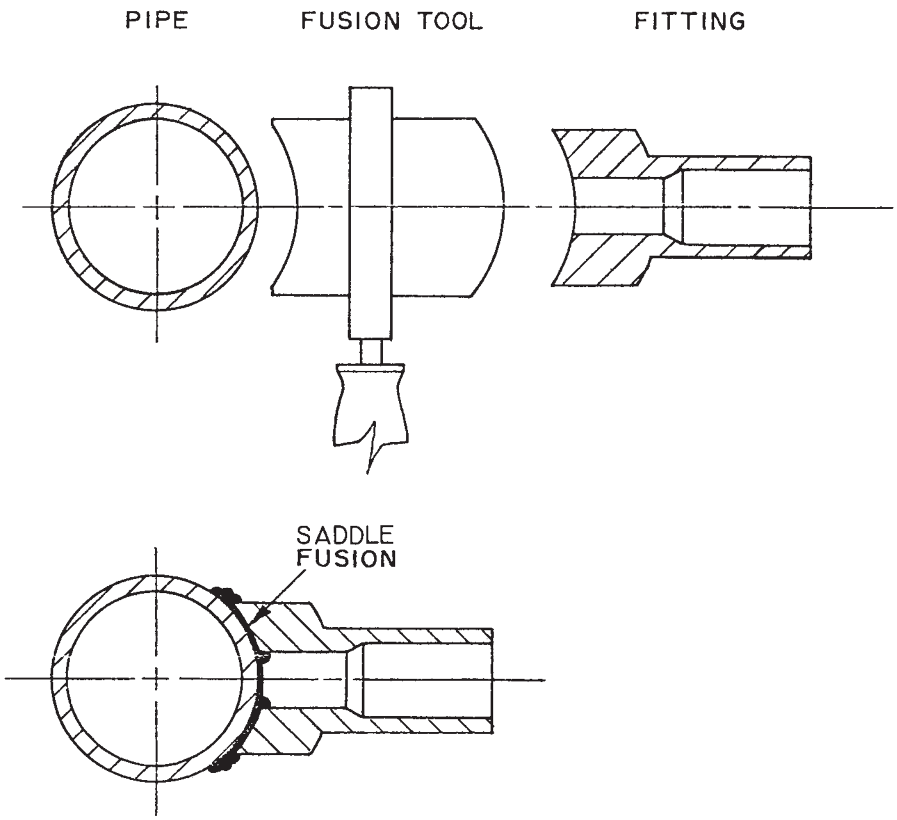

FIG. 3 Saddle Fusion

unless chromium-plated or clad with another suitable metal, because some polyolefins react with copper. Plastic materials may stick to hot metal heating surfaces. This sticking may be minimized by applying a non-stick coating to the heating surfaces or by fitting a high-temperature, non-stick fabric over the heating surfaces. The heating plate surfaces, coated or uncoated, shall be kept clean and free of contaminants such as dirt, grease and plastic build-up, which may cause excessive sticking and create unsatisfactory joints. Most of these contaminants are removed from the hot tool surfaces using a clean, dry, oil-free lint-free cloth. Do not use synthetic fabrics which may char and stick to the fusion surface. Some pigments, such as carbon black, may stain a heating surface and probably cannot be removed; such stains will not contaminate the joint interface.

6.2.1 After a period of time in service, non-stick coatings or fabrics will deteriorate and become less effective. Deteriorated fabrics should be replaced, and worn, scratched, or gouged non-stick coatings should be re-coated when they lose effectiveness. Heat fusion quality may be adversely affected by deteriorated non-stick surfaces. Spray-on chemicals, such as non-stick lubricants or oils shall not be applied to heating iron surfaces as they will contaminate the joint.

6.3 *Temperature Indicator*—Heating tools shall be equipped with a thermometer or other built-in temperature indicating device. This device indicates the internal temperature of the heating iron which is usually higher than temperature of the fusion surfaces. Use a pyrometer periodically to verify the temperature of the tool surfaces within the pipe or fitting contact area. Select multiple checkpoints to ensure uniform surface temperature.

NOTE 2—A significant temperature variation, that is, cold spots, on the fusion surfaces may indicate a faulty heating iron which may need to be serviced before it can be used.

7. Procedure 1—Socket Fusion

7.1 *Apparatus*—Socket fusion tools manufactured in accordance with Specification F 1056 are used for joining polyethylene pipe, tubing, and fittings.

7.1.1 *Heating Tool*—In order to obtain a proper melt, it is necessary for a uniform temperature to be maintained across the heating surface. Therefore, gas-fired tools are generally restricted to use with pipe sizes of 2 in. IPS (63 mm) or less.

7.1.2 *Heating Tool Faces*—Consisting of two parts, a male end for the interior socket surface and a female end for the exterior pipe surface. Both parts shall be made to such tolerances as to cause an interference fit.

7.1.3 *Alignment Jig*—The alignment jig is an optional tool which consists of two sets of devices holding the components in alignment to each other. One set of holding devices is fixed, and the other allows longitudinal movement for making the joint.

7.1.4 *Rounding Clamps*, (cold ring) to maintain roundness of the pipe and control the depth of pipe insertion into the socket during the joining operation.

7.1.5 *Depth Gage*, for proper positioning of the rounding clamp.

7.1.6 *Chamfering Tool*, to bevel the end of the pipe.

NOTE 3—The depth gage and chamfering tool may be combined into a single tool.

7.1.7 *Tubing Cutter*, to obtain a square end cut on the pipe.

7.1.8 *Fitting Puller*, an optional tool to assist in the removal of the fitting from the heating tool and to hold the fitting during assembly.

7.2 *Procedure*:

7.2.1 Attach the proper size heater faces to the heating tool, and heat the tool to the fusion temperature for the material.

7.2.2 Cut the pipe end squarely, and clean the pipe end and fitting, both inside and outside, by wiping with a clean, dry, oil-free, lint-free cloth.

7.2.3 Chamfer the outside edge of the pipe end slightly and fix the rounding clamp about the pipe as determined from the depth gage.

NOTE 4—Chamfering may not be required by some procedures or some fusion tools. Pipe sizes 1 in. (25.4 mm) and smaller are not usually chamfered, regardless of tooling design.

NOTE 5—Some recommend using a 50 to 60-grit emery or garnet cloth to roughen the outside of the pipe and inside of the fitting as a means of minimizing any possible skin interface when making the fusion. Sandpaper is not recommended for this purpose, as it might disintegrate and contaminate the joint interface. If roughening is performed, first clean the surfaces before roughening. Clean dust and particles from the roughened surfaces afterwards by wiping with a clean, dry, oil-free, lint-free cloth.

7.2.4 Bring the preheated tool faces into contact with the outside surface of the end of the pipe and the inside surface of the socket.

7.2.5 Heat the pipe end and the fitting socket for the time required to obtain a proper melt. Proper melt is a function of material, time, tool temperature, and the size of the parts. Pipe and fittings of larger diameters require more time to reach the proper melt consistency than those of smaller diameters. Underheated or overheated materials will not form a good bond.

7.2.6 At the end of the heating time, simultaneously remove the pipe and fitting straight out from the tool, using a snap action. Immediately insert the pipe straight into the socket of the fitting so the rounding clamp is flush against the end of the fitting socket. Hold or block the joint in place until the melts of the mating surfaces have solidified. The exact cooling time depends on the size of the pipe and the material being fused.

7.2.7 Remove the rounding clamp, and inspect the melt pattern at the end of the socket for a complete impression of the rounding clamp in the melt surface. There shall no gaps, voids, or unbonded areas. Clean the heating tool of any residual material using a wood stick or a clean, dry, oil-free, lint-free, non-synthetic cloth. Take care not to damage the heating surfaces. Plastic left on the tool tends to char when reheated, causing a loss of heater efficiency and joint contamination.

7.2.8 Allow for extremes in weather when making field joints. Heating times, operation of alignment jig, dimensional changes, and the like, are affected by extreme conditions.

7.3 *Testing*—Evaluate sample joints in order to verify the skill and knowledge of the fusion operator. Cut joints into straps, (see Fig. 4) and visually examine and test for bond continuity and strength. Bending, peeling, and elongation tests are useful for this purpose.

8. Procedure 2—Butt Fusion

8.1 *Apparatus*:

8.1.1 *Heating Tool*—The heating tool shall have sufficient area to adequately cover the ends of the size of pipe to be joined.

8.1.2 *Alignment Jig*—The alignment jig is three basic parts: (*1*) a stationary clamping fixture and a movable clamping fixture for holding each of the two parts to be fused in alignment; (*2*) a facer for simultaneously preparing the ends of the parts to be joined (Note 6); and (*3*) appropriate adapters for different pipe sizes. Alignment jigs are manually or hydraulically powered.

NOTE 6—A facer is a rotating cutting device used to square-off the pipe or fitting ends to obtain properly mating fusion surfaces.

8.2 *Procedure*:

8.2.1 Bring the heater plate surfaces to proper temperature.

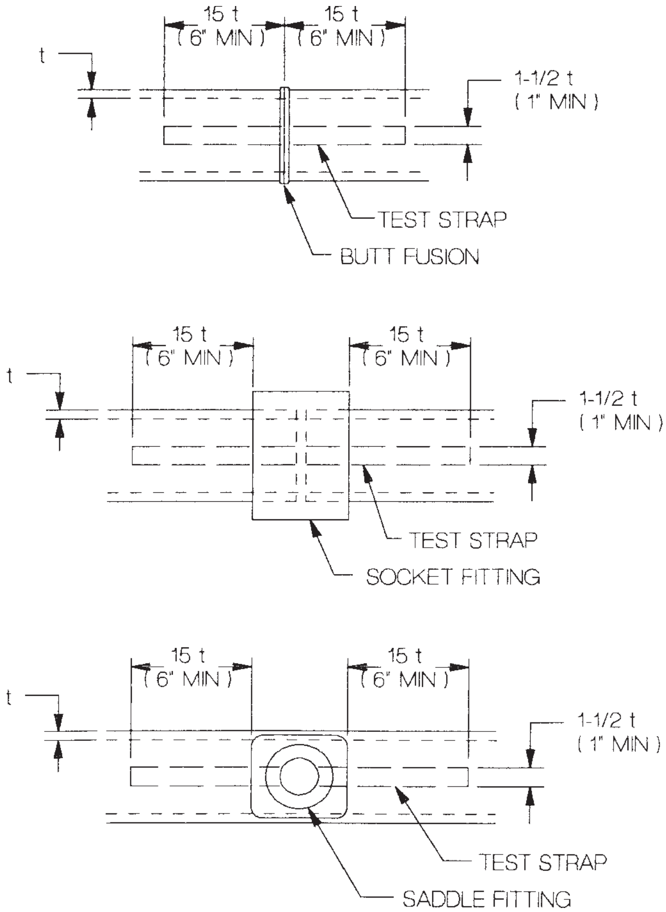

FIG. 4 Bent Strap Test Specimen

8.2.1.1 For butt fusion in accordance wiht PPI TR-33, the heating tool surfaces are set for a temperature from 400 to 450°F (204 to 232°C).

8.2.2 Clean the inside and outside of the components (pipe or pipe and fitting) to be joined. Remove all foreign matter from the surface of the component where it will be clamped in the alignment jig.

8.2.3 Align each component with its alignment jig clamp, and close the clamp. Check component to component alignment, adjust as needed, and face off the ends.

8.2.3.1 Take care when placing pipe or fittings in the alignment jig. Pipes shall be aligned before the alignment clamp is closed; however, do not force the pipe into alignment by pushing it against the side of an open alignment jig clamp.

8.2.4 Bring the piping components together and check for high-low alignment, and out-of-roundness. Adjust as required. Re-face after adjustment. The ends of the piping components shall be square to each other around their full circumference.

8.2.5 Place the heater plate between the component ends, and move the component ends against the heater plate with sufficient force to ensure complete circumferential contact against the heater plate. Hold the components against the heater plate briefly, using limited force to ensure that proper contact with the plate has been made. Release the force, but hold the components against the heater plate until an appropriately sized bead of molten plastic develops circumferentially around each component end as a result of the thermal expansion of the material. Do not push the components into the heater plate as the melting progresses.

8.2.5.1 For butt fusion in accordance with PPI TR-33, the melt bead size for 2in. IPS pipe is about 1⁄16 (1.6 mm) and is about 1⁄8 to 3⁄16 in. (3.2 to 4.8 mm) for 8 in. IPS.

8.2.6 Move the melted component ends away from the heater plate, and remove the heater plate. Quickly inspect the melted surfaces per 8.2.1. If the melt is accpetable, immediately bring the melted ends together with enough force to roll both component melt beads over to the pipe surface around the entire circumference of the joint. When the bead touches the pipe surface, stop moving the component ends together, but do not release the force. Hold the force on the joint until the joint has cooled.

8.2.6.1 Do not use excessive or insufficient force. If the components are brought together with too much force, all molten material may be pushed out of the joint and cold material brought into contact forming a "cold" joint. If too little force is used, only the melt in the beads may be fused together and, as the molten material in the joint cools and contracts, voids or non-fused areas may be formed. If the softened material sticks to the heater plate, discontinue the joining procedure. Clean the heater plate, re-square the component ends, and repeat the process from the beginning (8.2.2).

8.2.6.2 Inspect the component ends quickly when the heating tool is removed. The melt should be flat. A concave melt surface indicates unacceptable pressure during heating. If a concave melt surface is observed, do not continue. Allow the component ends to cool, and start over from 8.2.1.

8.2.6.3 For butt fusion in accordance with PPI TR-33, an interfacial pressure of 60 to 90 psi (0.41 to 0.62 MPa) is used to determine the force required to roll both fusion beads over to the pipe surface. For any pipe size and wall thickness, the actual fusion joining force is determined by multiplying the interfacial pressure by the area of the pipe end. To determine a fusion pressure gauge setting for hydraulic butt fusion machines, the force is divided by the area of the hydraulic cylinders that move the fusion machine carriage. The hydraulic fusion machine gauge pressure setting may need to be increased to overcome internal machine friction drag or to provide additional force to move pipes attached to the butt fusion machine.

8.2.7 Allow the assembly to stand at least until cool before removing the clamps or other aligning device (Note 7). Do not subject the joint to high stress until it has cooled to less than approximately 130°F. Do not apply internal pressure until the joint and surrounding material have reached ambient air temperature.

NOTE 7—The joint is usually cool enough to remove from the alignment jig if a bare hand can be held against the beads without discomfort (less than approximately 130°F). Further cooling is recommended prior to ditching the pipe.

8.2.8 Visually inspect the joint against recommended appearance guidelines. The beads should be uniformly shaped and sized all around the joint.

8.3 *Testing*—Evaluate sample joints to verify the skill and knowledge of the fusion operator. In some cases, butt-fusion joints can be nondestructively examined using ultrasonic equipment to detect voids or other discontinuities. Visually, the width of butt fusion beads should be 2 to 2-1/2 times the bead height above the pipe, and the beads should be rounded and uniformly sized all around the pipe circumference. The v-groove between the beads should not be deeper than half the bead height above the pipe surface. When butt fusing to molded fittings, the fitting-side bead may display shape irregularities such as minor indentations, deflections and non-uniform bead rollover from molded part cooling and knit lines. In such cases, visual evaluation is based mainly on the size and shape of the pipe-side bead. For destructive tests, cut joints into straps (see Fig. 4), visually examine, and test for bond continuity and strength. Tests that have been found useful for this purpose include inside face bend, outside face bend, tensile elongation, torque, and impact. Quantifiable data may be obtained by the use of laboratory procedures and comparing data against that from control samples.

9. Procedure 3—Saddle Fusion

9.1 *Apparatus*:

9.1.1 *Heating Tool Faces*—The faces are matched sets, by pipe size, of concave and convex blocks which bolt or clamp onto a flat or round core heater.

9.1.2 *Alignment Jigs*—Various types of alignment jigs are available. Alignment jigs provide a means to mount the alignment jig on the pipe, hold the fitting and align it to the pipe, and move the fitting towards and away from the pipe. Alignment jigs are used for saddle fusions for optimum results and are required for certain materials.

NOTE 8—Some materials may be saddle fused using a hand-stab procedure. Consult the manufacturer for a hand-stab procedure.

9.2 *Procedure*:

9.2.1 Bring heater plate and faces to proper temperature.

9.2.2 Clean the mating surfaces of the pipe and the concave surface of the fitting base and roughen the mating surfaces. Emery or garnet cloth of 50 to 60 grit is used to remove the tough outer surface skin. It is essential to remove the surface skin completely without altering the contours of the mating surfaces and to keep the surface clean. Remove dust and particles from the surface after roughing with a clean, dry, oil-free, lint-free cloth.

9.2.3 Install the alignment jig on the pipe. For smaller pipe sizes, install a bolster plate under the pipe to provide additional support.

9.2.4 Install the fitting in the alignment jig. Press the fitting against the pipe to align the fitting base to the pipe, then secure the fitting in the alignment jig.

9.2.5 Place the heater on the pipe and press the fitting against the heater to obtain a melt on both the pipe and the fitting.

NOTE 9—When saddle fittings are fused to pipes that are under pressure, it is important that the surface melt be obtained quickly without too much heat penetration. Otherwise, the pipe may rupture from internal pressure. Consult the manufacturer for specific recommendations for fusing saddle fittings to pipe under pressure.

9.2.6 When a proper melt is achieved, remove the heater, quickly examine the pipe and fitting to ensure proper melt patterns, and immediately place the fitting on the pipe. Hold in place while exerting suitable force for the specified cooling time.

NOTE 10—If a suitable melt pattern has not been achieved, do not reheat; however, continue with the fusion and apply the fitting to the pipe. When the joint has cooled, remove the alignment jig, cut off the top of the fitting to prevent use, and start over at another location.

9.3 Visually inspect the joint against recommended visual inspection guidelines.

9.4 *Testing*—Evaluate sample joints to verify the skill and knowledge of the fusion operator. Cut joints into straps (see Fig. 4), visually examine, and test for bond continuity and strength. See Practice F 905 for methods for evaluating the quality of fusion joints.

10. Keywords

10.1 butt fusion; fitting; heat fusion; joining; pipe; polybutylene; polyethylene; polyolefin; polypropylene; saddle fusion; socket fusion

ANNEX

(Mandatory Information)

A1. COLD WEATHER PROCEDURES

A1.1 *Cold Weather Handling*—Pipe should be inspected for damage. Polyolefin pipes have reduced impact resistance in sub-freezing conditions. Avoid dropping pipe in sub-freezing conditions. When handling coiled pipe at temperatures below 40°F, it is helpful to uncoil the pipe prior to installation and let it straighten out. Gradually uncoil the pipe and cover it with dirt at intervals to keep it from recoiling. Always use caution when cutting the straps on coils of pipe because the outside end of a coil may spring out when the strapping is removed.

A1.2 *Preparation for Socket, Saddle, and Butt Fusion Joining*:

A1.2.1 *Wind and Precipitation*—The heating tool should be shielded in an insulated container to prevent excessive heat loss. Shield the pipe fusion area and fusion tools from wind, snow, and rain by using a canopy or similar device.

A1.2.2 *Pipe and Fitting Surface Preparation*—The pipe and fitting surfaces to be "joined" or held in clamps should be dry and clean and free of ice, frost, snow, dirt, and other contamination. Regular procedures for preparation of surfaces to be joined, such as facing for butt fusion and roughening for saddle fusion should be emphasized. After preparation, the surfaces should be protected from contamination until joined. Contamination of the area to be fused will likely cause incomplete fusion. Frost and ice on the surfaces of the pipe to be clamped in either a cold ring or alignment jigs may cause slippage during fusion. Inspect coiled pipe to see if it has flattened during storage which could cause incomplete melt pattern or poor fusion. It may be necessary to remove several inches at the pipe ends to eliminate such distortion. Pipe may have a slight toe-in or reduced diameter for several inches at the end of the pipe. The toe-in may need to be removed before butt fusing to a freshly cut pipe end, or to a fitting.

A1.2.3 *Heating*—Work quickly once pipe and fitting have been separated from the heating tool, so that melt heat loss is minimized, but still take time (no more than 3 s) to inspect both melt patterns. Keep the heater dry at all times. Check the temperature of the heating tool regularly with a pyrometer. Keep the heating tool in an insulated container between fusions. Do not increase heating tool temperature above the specified temperature setting. Gas-fired heating tools are used only in above freezing conditions.

A1.3 *Socket Fusion*:

A1.3.1 *Pipe Outside Diameter*—Pipe outside diameter contracts when cold. This results in loose or slipping cold rings. For best results, clamp one cold ring in its normal position adjacent to the depth gage. Place shim material (that is, piece of paper or rag, etc.) around the inside diameter of a second rounding ring and clamp this cold ring directly behind the first cold ring to prevent slippage. The first cold ring allows the pipe adjacent to the heated pipe to expand to its normal diameter during the heating cycle.

A1.3.2 *Fitting Condition*—If possible, store socket fittings at a warm temperature, such as in a truck cab, prior to use. This will make it easier to place the fitting on the heating tool because fittings contract when cold.

A1.3.3 *Heating*—At colder temperatures the pipe and fitting contract, thus the pipe slips more easily into the heating tool. At very cold outdoor temperatures (particularly with 2, 3, and 4 in. IPS pipe), the pipe may barely contact the heating surface. Longer heating cycles are used so that the pipe first expands (from tool heat) to properly contact the heating tool, then develops complete melt. The length of cycle necessary to obtain a complete melt pattern will depend not only on the outdoor (pipe) temperature but wind conditions and operator variation. Avoid cycles in excess of that required to achieve a good melt pattern. To determine the proper cycle time for any particular condition, make a melt pattern on a scrap piece of pipe, using the heating cycle as instructed by the pipe manufacturer. If the pattern is incomplete (be sure rounding rings are being used), try a 3-s longer cycle on a fresh (cold) end of pipe. If the melt pattern is still not completely around the pipe end, add an additional 3 s and repeat the procedure. Completeness of melt pattern is the key. Keep the heater dry at all times. Check the temperature of the heating tool regularly and keep the heating tool in an insulated container between fusions.

A1.4 *Butt Fusion*:

A1.4.1 *Joining* — It will take longer to develop the initial melt bead completely around the pipe ends. Do not increase pressure during heating. When proper melt bead has been obtained, the pipe and heater shall be separated in a rapid, snap-like motion. The melted surfaces shall then be joined immediately in one smooth motion so as to minimize cooling of the melted pipe ends.

A1.5 *Saddle Fusion*:

A1.5.1 *Surface Preparations*—Regular procedures for roughening the surfaces to be fused on the pipe and the fitting should be emphasized. After the surfaces have been prepared, particular care should be taken to protect against contamination.

A1.5.2 *Heating Time*—Make a trial melt pattern on a scrap piece of pipe. A clean, dry piece of wood is used to push the heating tool against the pipe. If the melt pattern is incomplete, add 3 s to the cycle time and make another trial melt pattern on another section of cold pipe. If the pattern is still incomplete, continue 3-s additions on a fresh section of cold pipe until a complete melt pattern is attained. Use this heating cycle for fusions during prevailing conditions. Regardless of the weather or the type of tools used, the important point to remember is that complete and even melt must occur on the fitting and the pipe in order to produce a good fusion joint. This requires pipe preparation to make it clean, straight, round, and well supported.