Designation: D2513 – 16a

An American National Standard

Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings[1]

This standard is issued under the fixed designation D2513; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification covers requirements and test methods for material dimensions and tolerances, hydrostatic burst strength, chemical resistance, and rapid crack resistance of polyethylene pipe, tubing, and fittings for use in fuel gas mains and services for direct burial and reliner applications. The pipe and fittings covered by this specification are intended for use in the distribution of natural gas. Requirements for the qualifying of polyethylene systems for use with liquefied petroleum gas are also covered.

1.1.1 This specification does not cover threaded pipe. Design considerations are discussed in Appendix X1. In-plant quality control programs are specified in Annex A1 and Annex A2.

1.1.2 See Specification F2619/F2619M for polyethylene piping for pressure or non-pressure oil and gas producing applications to convey fluids such as oil, dry or wet gas, multiphase fluids, and non-potable oilfield water.

1.2 The text of this specification 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 specification.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following is an index of the annexes and appendix in this specification:

Annex	Subject
Annex A1	In-Plant Quality Control for all materials up to 12 in.
Annex A2	In-Plant Quality Control for PE materials 14 in. and larger.

Appendixes	Subject
Appendix X1	Design Consideration

1.5 The following precautionary caveat pertains only to the test method 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:*[2]

2.1.1 *Terminology:*

D1600 Terminology for Abbreviated Terms Relating to Plastics

F412 Terminology Relating to Plastic Piping Systems

2.1.2 *Test Methods for:*

D638 Test Method for Tensile Properties of Plastics

D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure

D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe

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

F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins

2.1.3 *Practices for:*

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D618 Practice for Conditioning Plastics for Testing

D1435 Practice for Outdoor Weathering of Plastics

D1898 Practice for Sampling of Plastics (Withdrawn 1998)[3]

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.60 on Gas.

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

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

D2774 Practice for Underground Installation of Thermoplastic Pressure Piping
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.1.4 *Specification for:*

D2683 Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
D3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
F1055 Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
F1563 Specification for Tools to Squeeze-off Polyethylene (PE) Gas Pipe or Tubing
F2138 Specification for Excess Flow Valves for Natural Gas Service
F2619/F2619M Specification for High-Density Polyethylene (PE) Line Pipe
F2897 Specification for Tracking and Traceability Encoding System of Natural Gas Distribution Components (Pipe, Tubing, Fittings, Valves, and Appurtenances)

2.2 *ANSI Standards:*

B 16.40 Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems[4]
B 31.8 Gas Transmission and Distribution Piping Systems[4]

2.3 *Federal Specifications:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[5]
OPS 49 CFR Part 192 Title 49, Code of Federal Regulations[5]

2.4 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[5]
MIL-STD-1235 (ORD) Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes

2.5 *ISO Standards*[6]:

ISO 4437 Buried polyethylene (PE) pipes for the supply of gaseous fuels-Metric series-Specifications
ISO 9080 Thermoplastics Pipes for the Transport of Fluids—Methods of Extrapolation of Hydrostatic Stress Rupture Data to Determine Long-Term Hydrostatic Strength of Thermoplastic Pipe Materials
ISO 12162 Thermoplastic Materials for Pipes and Fittings for Pressure Applications—Classification and Designation—Overall Service (Design) Coefficient
ISO 13477 Thermoplastics pipes for the conveyance of fluids – Determination of resistance to rapid crack propagation (RCP) – Small scale steady-state test (S4 test)
ISO 13478 Thermoplastics pipe for the conveyance of fluids – Determination of resistance to rapid crack propagation (RCP) – Full-scale test (FST)

2.6 *Plastic Pipe Institute*[7]

PPI TR-3 HDB/HDS /PDB/ SDB/MRS Policies
PPI TR-4 HDB/HDS/SDB/PDB/MRS Listed Materials
PPI TR-33 Generic Butt Fusion Joining for Polyethylene Gas Pipe
PPI TR-41 Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping[7]
PPI TN-30/2006 Requirements for the Use of Rework Materials in Polyethylene Gas Pipe[7]
PPI TR-9 Recommended Design Factors and Design Coefficients for Thermoplastic Pressure pipe

2.7 *Other Documents:*[8]

National Fire Protection Association: NFPA 58 Storage and Handling Liquefied Petroleum Gases

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 The gas industry terminology used in this specification is in accordance with ANSI B31.8 or OPS 49 CFR Part 192, unless otherwise indicated.

3.3 The term *pipe* used herein refers to both pipe and tubing unless specifically stated otherwise.

3.4 *re-rounding equipment*—equipment used to reform the pipe and permanently reduce ovality to 5 % or less.

3.5 *rounding equipment*—equipment, devices, clamps, and so forth, used to temporarily hold the pipe round while out-of-roundness measurements are made, or a joining procedure (heat fusion, electrofusion, or mechanical) is performed.

3.6 *pipe material designated code*—the pipe material designation code shall consist of the abbreviation for the type of plastic (PE) followed by Arabic numerals which describe the short term properties in accordance with applicable Specification D3350, the hydrostatic design stress for water at 73.4°F (23°C) in units of 100 psi with any decimal figures dropped. Where the hydrostatic design stress code contains less than two figures, a zero is used before the number. Thus, a complete material designation code shall consist of PE and four figures for PE materials. For example, PE2708 is a grade PE27 polyethylene with an 800psi design stress for water at 73.4°F (23°C). The hydrostatic design stresses for gas are not used in this designation code.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.
[6] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.
[7] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.
[8] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

3.7 *dimension ratio (DR)*—the ratio of pipe diameter to wall thickness. It is calculated by dividing the specified outside diameter of the pipe, in inches (mm), by the minimum specified wall thickness, in inches (mm). The standard dimension ratio (SDR) is a common numbering system which is derived from the ANSI preferred number series R 10.

3.8 *toe-in*—a small reduction of the outside diameter at the cut end of a length of thermoplastic pipe.

4. Materials

4.1 *General*—The PE used to make pipe and fittings shall be PE or reworked PE (see 4.2 and 4.4) and shall have a Plastics Pipe Institute (PPI) long-term hydrostatic design stress and hydrostatic design basis rating.

4.2 *Rework Material*—Clean rework material of the same commercial designation, generated from the manufacturer's own pipe and fitting production shall not be used unless the pipe and fitting produced meet all the requirements of this specification. The use of these rework materials shall be governed by the requirements of 4.3 and PPI TN-30/2006. In pipe, rework materials shall be limited to a maximum of 30 % by weight.

NOTE 1—The requirements for rework materials herein are intended to incorporate prudent specifications to ensure that the potential for contamination in gas piping products, that meet this specification, is reduced to the extent possible. It is imperative to emphasize that rework materials have not been identified as the cause of any field failures. The requirements for rework materials were developed by the consensus of interested parties including product manufacturers, gas utility companies, and regulatory agencies.

4.3 *Documentation*—A documentation system to allow for traceability of raw materials including percentage and material classification (or designation, if applicable) of rework materials used in the manufacture of the pipe product meeting the requirements of this specification shall exist and be supplied to the purchaser, if requested.

4.4 *Classification*—Polyethylene materials suitable for use in the manufacture of pipe and fittings under this specification shall meet Table 1 requirements for the applicable pipe material designation code.

NOTE 2—References and material descriptions for PE 2306, PE 2406, PE 2606, PE 3306, PE 3406, PE 3408, PE 3608, PE 3710, and PE 4608 have been removed from D2513. Elimination of these materials does not affect the pipelines that are in service. They can still be used for gas distribution. The main reason for removing these materials from this standard is to reflect the current state of the art in PE gas distribution piping.

4.5 *Resistance to Slow Crack Growth (SCG)*—Use Test Method F1473 on compression molded plaques at a stress of 2.4 MPa based on the unnotched area and a test temperature of 80°C. Notch depth shall be in accordance with Table 1 in Test Method F1473. Materials shall meet the Slow Crack Growth Resistance requirements in Table 1.

4.6 *Additive Classes*—Polyethylene material compounds shall meet Specification D3350 code C or E. Code C material compounds shall have 2 to 3 percent carbon black. Code E material compounds shall be yellow with UV stabilizer.

4.7 *Thermal Stability*—The PE material shall contain sufficient antioxidant so that the minimum induction temperature shall be 428°F (220°C) when tested in accordance with Specification D3350. The sample shall be representative of the cross section of the pipe or fittings.

4.8 *Hydrostatic Design Basis (HDB) Substantiation* —The HDB for PE materials at 73°F (23°C) shall be substantiated to be linear to 50 years as per Test Method D2837, Section 5.7.

NOTE 3—The long-term hydrostatic strength at 50 years in accordance with Test Method D2837 is not to be used for any pressure rating calculations. The MAOP is still calculated using the HDB obtained from Test Method D2837 long-term hydrostatic strength at 100 000 h. PE compounds with a thermoplastic pipe material designation code of PE 2708 and PE 4710 as well as those compounds denoted in PPI TR-4 with an asterisk (*) meet the substantiation requirement of Test Method D2837.

4.9 *Resistance to Rapid Crack Propagation (RCP) for Material* —The PE material classification (formulation) used in the manufacture of pipe and fittings under this specification shall be tested for resistance to failure by RCP in accordance with the procedures set forth in ISO 13477 (S4 Test) or ISO 13478 (Full Scale Test (FST)). The data obtained shall be made available upon request without limitations on disclosure, and shall not subsequently be subject to disclosure limitations when used by others. The values obtained are applicable to all pipes with the wall thickness of the pipe tested and all thinner wall pipes. In case of conflict, the RCP results of ISO 13478 shall apply.

NOTE 4—While S4 or FST testing of any combination of outside diameter and SDR is permitted in fulfillment of the requirement for testing

TABLE 1 Polyethylene Compound Requirements

	Pipe Material Designation Code	
	PE 2708	PE 4710
Density Cell Classification per Specification D3350	2	4
SCG Resistance Cell Classification per Specification D3350	7	7
HDS for water at 73°F (23°C) per Test Method D2837 and PPI TR-3, psi (MPa)	800 (5.5)	1000 (6.9)
Color and UV Stabilizer Code per Speciif-cation D3350	C or E	C or E
Melt flow rate per Test Method D1238, g/10 min	≤0.40 Cond. 190/2.16 or ≤20 Cond. 190/21.6	≤0.15 Cond. 190/2.16 or ≤20 Cond. 190/21.6
HDB at 73ºF (23ºC) per Test Method D2837 and PPI TR-3, psi (MPa)	1250 (8.6)	1600 (11.0)
Minimum HDB at 140ºF (60ºC) per Test Method D2837 and PPI TR-3, psi (MPa)	800 (5.5)	800 (5.5)

PE material resistance to RCP, S4 testing of SDR 9 or SDR 11 PE pipe specimens is currently the most common industry practice.

NOTE 5—Caution should be exercised in applying the RCP test results obtained on one SDR or DR of pipe across a series of pipe SDR's or DR's produced from the same PE material classification (formulation). Industrial research to clarify the relationships between FST and S4 testing is ongoing at this time, particularly as it relates to the applicability of RCP test results obtained on one SDR or DR of pipe to other SDR's or DR's of pipe produced from the same PE material classification (formulation). Consult the resin manufacturer regarding the applicability of RCP test results across diameters or SDR's, or both. Additional information regarding the use of RCP data is presented in ISO 4437.

4.10 *UV Resistance*—PE materials shall be Code C or E as defined in Specification D3350. Code C material shall contain 2 to 3 percent well dispersed carbon black, and due to the absorptive properties of the carbon black, is considered to be stabilized against deterioration from unprotected exposure to UV for not less than 10 years. Code E material shall be stabilized and protected against deterioration from unprotected UV exposure for not less than 3 years.

4.10.1 PE compounds designated as Code C containing 2 to 3% carbon black shall be considered stabilized against deterioration for not less than 10 years without the need for additional testing. Black PE pipe coextruded with yellow stripe(s) shall be considered stabilized against deterioration from unprotected exposure to UV for not less than 10 years.

NOTE 6—Consult with pipe manufacturer on UV Resistance of black pipes with yellow stripe(s) for conformance to the performance requirements of code "C" material.

4.10.2 PE compounds designated as Code E shall be considered stabilized against deterioration from unprotected exposure to UV for not less than 3 years when meeting the following criteria following exposure to actual outdoor (natural sunlight) weathering for up to 3 years in accordance with Practice D1435 or accelerated weathering in accordance with Practice D2565 and Practice G155 for the equivalent of at least 3 years natural sunlight: (a) all tensile bar specimens tested in accordance with Test Method D638 shall have an elongation at break value greater than 400% indicating the equivalency of the PE material before and after UV exposure against the elongation at break requirement in Specification D3350; and (b) all tensile bar specimens tested in accordance with Test Method D638 shall retain a minimum of 50% of their original elongation at break values. Test data shall be made available from the manufacturer upon request.

NOTE 7—Studies have shown HDPE exposed to Xenon Arc via Practice G155-A Cycle 1 give approximately 4.4 times the acceleration to outdoor Florida exposure. Therefore approximately 2000 hours Xenon Arc testing would equal about 1-year outdoor exposure in Florida or 2-years in southern Canada.

NOTE 8—The determination for UV resistance is often based on measuring the ductility properties of the pipe material exposed to artificial weathering. These requirements and test methods are based on expected UV exposure levels in North America. Alternate requirements and alternate determination methods may be appropriate in other regions of the world. As an example ISO 4437 standard requires a minimum resistance to an accumulation of 3.6GJ for non-black polyethylene materials.

4.11 *Qualification for LPG Service*—Materials that qualify for natural gas service and that carry a recommended HDB for 140°F in accordance with 5.6, also qualify for LPG service without the need for further testing.

NOTE 9—The terms LPG and LPG gas are synonymous and only apply to a particular kind of fuel gas. For compositions and properties of LPG gases see NFPA 58, Appendix B.

5. Requirements

5.1 *General*—Pipe shall be supplied in either coils or straight lengths. Any pipe supplied in coils must meet the same requirements before and after coiling.

5.2 *Workmanship*—The pipe and fittings shall be homogeneous throughout and free of visible cracks, holes, foreign inclusion, blisters, and dents, or other injurious defects. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

5.3 *Pipe and Tubing Dimensions and Tolerances:*

5.3.1 *Dimension*—The dimensions shall be specified by wall thickness and outside diameter.

5.3.1.1 *Diameters*—The outside diameter shall meet the requirements given in Table 2 or Table 3 when measured in accordance with 6.5.

5.3.1.2 *Toe-In*—When measured in accordance with 6.5.1.1, 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 the requirements of Table 2 or Table 3.

5.3.1.3 *Wall Thickness*—The wall thickness shall be as specified in Table 3 or Table 4 when measured in accordance with 6.5.1.2. The minimum wall thickness at any point of measurement shall be not less than the minimum wall thickness specified in Table 3 or Table 4.

5.3.1.4 *Wall Thickness Eccentricity Range*—The wall thickness eccentricity range shall be within 12 % when measured in accordance with 6.5.1.3.

5.3.1.5 *Ovality*—The ovality (cross section) of 3 in. IPS (88.9 mm) and smaller pipe shall not exceed 5 % when measured in accordance with 6.5.3. Measurements of coiled pipe shall be made on a sample cut from the coil, and in case of disagreement, conditioned per 6.3.

NOTE 10—Other factors, that is, installation compaction, static soil loading, and dynamic vehicular loads may increase the ovality; therefore, 5 % was chosen as the limit for the amount contributed by manufacturing, packing, in-plant storage, and shipping. For further information, see **(1)**[9].

(1) Before or during installation, coiled pipe larger than 3 in. IPS (88.9 mm) shall be processed by the installer through re-rounding equipment that corrects ovality to 5 % or less.

NOTE 11—Ovality is a packaging condition that occurs when roundable pipe is wound into a coil—the pipe flattens out as it is coiled. Ovality is corrected when joining equipment is applied to roundable pipe, or by field processing roundable pipe through re-rounding and straightening equipment during installation.

5.3.1.6 *Length*—The pipe shall be supplied in straight lengths or coils as agreed upon between the manufacturer and the purchaser. The length shall not be less than the minimum length agreed upon when corrected to 73°F (23°C).

[9] The boldface numbers in parentheses refer to a list of references at the end of this standard.

TABLE 2 Outside Diameters and Tolerances for Plastic Pipe, in. (mm)

Nominal Pipe Size	Outside Diameter	Tolerance	Maximum Out-of-Roundness			
			SDR 32.5	SDR 26	SDR 21	SDR 17 SDR 13.5 SDR 11
½	0.840 (21.3)	±0.004 (±0.102)	...	...	0.03(0.762)	0.016(0.406)
¾	1.050 (26.7)	±0.004 (±0.102)	...	...	0.03(0.762)	0.02(0.508)
1	1.315 (33.4)	±0.005 (±0.127)	...	...	0.03(0.762)	0.02(0.508)
1¼	1.660 (42.1)	±0.005 (±0.127)	...	...	0.03(0.762)	0.024(0.61)
1½	1.900 (48.3)	±0.006 (±0.152)	...	...	0.06(1.524)	0.024(0.61)
2	2.375 (60.3)	±0.006 (±0.152)	...	...	0.06(1.524)	0.024(0.61)
2½	2.875 (73.0)	±0.007 (±0.179)	...	...	0.06(1.524)	0.03(0.762)
3	3.500 (88.9)	±0.008 (±0.203)	...	...	0.06(1.524)	0.03(0.762)
3½	4.000 (101.6)	±0.008 (±0.203)	...	...	0.1(2.5)	0.03(0.762)
4	4.500 (114.3)	±0.009 (±0.229)	...	...	0.1(2.5)	0.03(0.762)
5	5.563 (141.3)	±0.010 (±0.254)	...	...	0.1(2.5)	0.06(1.524)
6	6.625 (168.3)	±0.011 (±0.279)	0.12(3)	0.11(2.74)	0.1(2.5)	0.07(1.778)
8	8.625 (219.1)	±0.013 (±0.330)	0.24(6.1)	0.16(4.06)	0.12(3)	0.08(2.04)
10	10.750 (273.0)	±0.015 (±0.381)	0.24(6.1)	0.2(5.08)	0.14(3.58)	0.1(2.5)
12	12.750 (323.8)	±0.017 (±0.432)	0.28(7.12)	0.2(5.08)	0.14(3.58)	0.1(2.5)
14	14.000 (355.6)	±0.063 (±1.60)	0.308(7.82)	0.224(5.68)	0.154(3.91)	0.112(2.84)
16	16.000 (406.4)	±0.072 (±1.83)	0.352(8.94)	0.256(6.50)	0.176(4.47)	0.128(3.25)
18	18.000 (457.2)	±0.081 (±2.06)	0.396(10.05)	0.288(7.31)	0.198(5.02)	0.144(3.65)
20	20.000 (508.0)	±0.090 (±2.29)	0.44(11.1)	0.32(8.12)	0.22(5.58)	0.16(4.06)
22	22.000 (558.8)	±0.099 (±2.51)	0.484(12.29)	0.352(8.94)	0.242(6.14)	0.176(4.47)
24	24.000 (609.6)	±0.108 (±2.74)	0.528(13.41)	0.384(9.75)	0.264(6.70)	0.192(4.87)

TABLE 3 PE Tubing-Diameters, Wall Thicknesses, and Tolerances, in. (mm)

Nominal Tubing Size (CTS)	Outside Diameter	Tolerance	Minimum Wall Thickness	Wall Thickness Tolerance
¼	0.375 (9.52)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
⅜	0.500 (12.7)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
½	0.625 (15.9)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
½	0.625 (15.9)	±0.004 (±0.10)	0.090 (2.27)	+0.009 (+0.23)
½	0.625 (15.9)	±0.004 (±0.10)	0.104 (2.64)	+0.010 (+0.25)
¾	0.875 (22.2)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
¾	0.875 (22.2)	±0.004 (±0.10)	0.077 (1.95)	+0.008 (+0.20)
¾	0.875 (22.2)	±0.004 (±0.10)	0.090 (2.27)	+0.009 (+0.23)
1	1.125 (28.6)	±0.005 (±0.13)	0.062 (1.58)	+0.007 (+0.18)
1	1.125 (28.6)	±0.005 (±0.13)	0.090 (2.27)	+0.011 (+0.28)
1	1.125 (28.6)	±0.005 (±0.13)	0.099 (2.51)	+0.012 (+0.31)
1	1.125 (28.6)	±0.005 (±0.13)	0.101 (2.56)	+0.012 (+0.31)
1	1.125 (28.6)	±0.005 (±0.13)	0.121 (3.07)	+0.015 (+0.38)
1¼	1.375 (34.9)	±0.005 (±0.13)	0.062 (1.58)	+0.007 (+0.18)
1¼	1.375 (34.9)	±0.005 (±0.13)	0.090 (2.27)	+0.011 (+0.28)
1¼	1.375 (34.9)	±0.005 (±0.13)	0.121 (3.07)	+0.015 (+0.38)
1¾	1.875 (47.6)	±0.006 (±0.15)	0.062 (1.58)	+0.007 (+0.18)

5.3.1.7 When sizes other than those listed in Table 2, Table 3 or Table 4 are used, tolerances shall be: for outside diameter, use same tolerance of next smaller size; for wall thickness, use same tolerance percentage as shown in the tables.

5.4 *Minimum Hydrostatic Burst Pressure/Apparent Tensile Strength (Quick Burst)*—The pipe or system shall fail in a ductile manner when tested in accordance with Test Method D1599. For pipe sizes above 4-in. nominal diameter, the testing lab shall be allowed to replace the quick burst test (Test Method D1599) by the apparent ring tensile strength test (Test Method D2290). The minimum apparent tensile strength at yield when determined in accordance with 6.8 shall be 2520 psi (17.4 MPa) for PE 2708 pipe or 2900 psi (20.0 MPa) for PE 4710 pipe.

NOTE 12—The requirements in 5.3.1.1 and 5.3.1.3 are for laboratory proof testing only and should not be interpreted as applicable to on-site testing for acceptance of installed systems larger than 12 in. See appropriate installation standards or manufacturer's recommendations for field test procedures.

5.5 *Chemical Resistance*—The pipe and fittings shall not increase in weight more than 0.5 % (1.0 % for toluene in methanol). Where the test specimen is a pipe ring, the material shall not change more than ±12 % in apparent tensile yield strength when measured in accordance with 6.9. Where the test specimen is a plaque, the material shall not change more than ±12 % in tensile strength at yield when measured in accordance with Test Method D638.

NOTE 13—This pipe test is only an indication of what will happen as a result of short term exposure to these chemicals. For longterm results, additional testing is required.

5.6 *Melt Index*—Melt index is the flow rate of PE material when measured in accordance with Test Method D1238, condition 190/2.16 (formerly Condition E). Materials that record zero flow under condition 190/2.16 shall be measured in accordance with condition 190/21.6 (formerly condition F). The melt index of pipe/fitting shall meet the designated category in Table 5. The sample shall be representative of the cross section of the pipe or fitting and diced to an appropriate size by a method not producing heat.

5.7 *Sustained Pressure 73°F (23°C)*—Fittings shall not fail in less than 1000 h when tested in accordance with Test Method D1598. For PE 2708 materials, the stress shall be 1320 psi, for PE 4710 materials, the stress shall be 1600 psi.

TABLE 4 Wall Thicknesses and Tolerances for Plastic Pipe, in (mm)[A,B]

Nominal Pipe Size (IPS)	DR[C]	Minimum	Tolerance
½	[D]	0.062 (1.58)	+0.007 (+0.178)
	11.0	0.076 (1.93)	+0.009 (+0.229)
	9.33	0.090 (2.29)	+0.011 (+0.279)
¾	[D]	0.090 (2.29)	+0.011 (+0.279)
	11.0	0.095 (2.41)	+0.011 (+0.279)
	Sch 40	0.113 (2.87)	+0.014 (+0.356)
1	[D]	0.090 (2.29)	+0.011 (+0.279)
	13.5	0.097 (2.46)	+0.012 (+0.305)
	11.0	0.120 (3.05)	+0.014 (+0.356)
	9.9	0.133 (3.38)	+0.016 (+0.406)
	9.33	0.140 (3.56)	+0.017 (+0.432)
1¼	[D]	0.090 (2.29)	+0.011 (+0.279)
	17.0	0.098 (2.49)	+0.012 (+0.305)
	13.5	0.123 (3.12)	+0.015 (+0.381)
	Sch 40	0.140 (3.56)	+0.017 (+0.432)
	11.0	0.151 (3.84)	+0.018 (+0.457)
	10.0	0.166 (4.22)	+0.020 (+0.508)
	9.33	0.178 (4.52)	+0.021 (+0.533)
	6.0	0.277 (7.04)	+0.033 (+0.838)
1½	[D]	0.090 (2.29)	+0.011 (+0.279)
	17	0.112 (2.85)	+0.013 (+0.330)
	13.5	0.141 (3.58)	+0.017 (+0.432)
	Sch 40	0.145 (3.68)	+0.017 (+0.432)
	11	0.173 (4.39)	+0.021 (+0.533)
2	21	0.113 (2.87)	+0.014 (+0.356)
	17	0.140 (3.56)	+0.017 (+0.432)
	Sch 40	0.154 (3.91)	+0.018 (+0.457)
	13.5	0.176 (4.47)	+0.021 (+0.533)
	11	0.216 (5.49)	+0.026 (+0.660)
	9.33	0.255 (6.48)	+0.031 (+0.787)
2½	21	0.137 (3.48)	+0.016 (+0.406)
	17	0.169 (4.29)	+0.020 (+0.508)
	13.5	0.213 (5.41)	+0.026 (+0.660)
	11	0.261 (6.63)	+0.031 (+0.787)
3	21	0.167 (4.24)	+0.020 (+0.508)
	17	0.206 (5.23)	+0.025 (+0.635)
	Sch 40	0.216 (5.49)	+0.026 (+0.660)
	13.5	0.259 (6.58)	+0.031 (+0.787)
	11.5	0.304 (7.72)	+0.036 (+0.914)
	11	0.318 (8.08)	+0.038 (+0.965)
	9.33	0.375 (9.53)	+0.045 (+1.143)
3½	21	0.190 (4.83)	+0.023 (+0.584)
	17	0.236 (5.99)	+0.028 (+0.711)
	13.5	0.296 (7.52)	+0.036 (+0.914)
	11	0.363 (9.22)	+0.044 (+1.118)
4	21	0.214 (5.44)	+0.026 (+0.660)
	19	0.237 (6.02)	+0.028 (+0.711)
	17	0.265 (6.73)	+0.032 (+0.813)
	13.5	0.333 (8.46)	+0.040 (+1.016)
	11.5	0.391 (9.93)	+0.047 (+1.194)
	11.0	0.409 (10.39)	+0.049 (+1.246)
	9.33	0.482 (12.24)	+0.058 (+1.473)
5	21.6	0.258 (6.55)	+0.031 (+0.787)
	21	0.265 (6.73)	+0.032 (+0.813)
	17	0.327 (8.31)	+0.039 (+0.991)
	13.5	0.412 (10.46)	+0.050 (+1.270)
	11	0.506 (12.85)	+0.061 (+1.549)
6	32.5	0.204 (5.18)	+0.024 (+0.610)
	26	0.255 (6.48)	+0.031 (+0.787)
	23.7	0.280 (7.11)	+0.034 (+0.864)
	21	0.315 (8.00)	+0.038 (+0.965)
	17	0.390 (9.91)	+0.047 (+1.194)
	13.5	0.491 (12.47)	+0.059 (+1.499)

TABLE 4 *Continued*

Nominal Pipe Size (IPS)	DR[C]	Minimum	Tolerance
	11.5	0.576 (14.63)	+0.069 (+1.753)
	11.0	0.602 (15.29)	+0.072 (+1.829)
8	32.5	0.265 (6.73)	+0.032 (+0.813)
	26	0.332 (8.43)	+0.040 (+1.016)
	21	0.411 (10.44)	+0.049 (+1.245)
	17	0.507 (12.90)	+0.061 (+1.549)
	13.5	0.639 (16.23)	+0.077 (+1.956)
	11.5	0.750 (19.05)	+0.090 (+2.286)
	11	0.784 (19.91)	+0.094 (+2.388)
10	32.5	0.331 (8.41)	+0.040 (+1.016)
	26	0.413 (10.49)	+0.050 (+1.270)
	21	0.512 (13.00)	+0.061 (+1.549)
	17	0.632 (16.05)	+0.076 (+1.930)
	13.5	0.796 (20.22)	+0.096 (+2.438)
	11.5	0.935 (23.75)	+0.112 (+2.845)
	11	0.977 (24.82)	+0.117 (+2.972)
12	32.5	0.392 (9.96)	+0.047 (+1.194)
	26	0.490 (12.45)	+0.059 (+1.499)
	21	0.607 (15.42)	+0.073 (+1.854)
	17	0.750 (19.05)	+0.090 (+2.286)
	13.5	0.944 (23.98)	+0.113 (+2.870)
	11.5	1.109 (28.17)	+0.133 (+3.378)
	11	1.159 (29.44)	+0.139 (+3.531)
14	32.5	0.431 (10.942)	+0.052 (+1.313)
	26	0.538 (13.677)	+0.065 (+1.641)
	21	0.667 (16.933)	+0.080 (+2.032)
	17	0.824 (20.918)	+0.099 (+2.510)
	13.5	1.037 (26.341)	+0.124 (+3.161)
	11.5	1.217 (30.922)	+0.146 (+3.711)
	11	1.273 (32.327)	+0.153 (+3.879)
16	32.5	0.492 (12.505)	+0.059 (+1.501)
	26	0.615 (15.631)	+0.074 (+1.876)
	21	0.762 (19.352)	+0.091 (+2.322)
	17	0.941 (23.906)	+0.113 (+2.869)
	13.5	1.185 (30.104)	+0.142 (+3.612)
	11.5	1.391 (35.339)	+0.167 (+4.241)
	11	1.455 (36.945)	+0.175 (+4.433)
18	32.5	0.554 (14.068)	+0.066 (+1.688)
	26	0.692 (17.585)	+0.083 (+2.110)
	21	0.857 (21.771)	+0.103 (+2.613)
	17	1.059 (26.894)	+0.127 (+3.227)
	13.5	1.333 (33.867)	+0.160 (+4.064)
	11.5	1.565 (39.757)	+0.188 (+4.771)
	11	1.636 (41.564)	+0.196 (+4.988)
20	32.5	0.615 (15.631)	+0.074 (+1.876)
	26	0.769 (19.538)	+0.092 (+2.345)
	21	0.952 (24.190)	+0.114 (+2.903)
	17	1.176 (29.882)	+0.141 (+3.586)
	13.5	1.481 (37.630)	+0.178 (+4.516)
	11.5	1.739 (44.174)	+0.209 (+5.301)
	11	1.818 (46.182)	+0.218 (+5.542)
22	32.5	0.677 (17.194)	+0.081 (+2.063)
	26	0.846 (21.492)	+0.102 (+2.579)
	21	1.048 (26.610)	+0.126 (+3.193)
	17	1.294 (32.871)	+0.155 (+3.944)
	13.5	1.630 (41.393)	+0.196 (+4.967)
	11.5	1.913 (48.591)	+0.230 (+5.831)
	11	2.000 (50.800)	+0.240 (+6.096)
24	32.5	0.738 (18.757)	+0.089 (+2.251)
	26	0.923 (23.446)	+0.111 (+2.814)
	21	1.143 (29.029)	+0.137 (+3.483)

TABLE 4 *Continued*

Nominal Pipe Size (IPS)	DR[C]	Minimum	Tolerance
	17	1.412 (35.859)	+0.169 (+4.303)
	13.5	1.778 (45.156)	+0.213 (+5.419)
	11.5	2.087 (53.009)	+0.250 (+6.361)
	11	2.182 (55.418)	+0.262 (+6.650)

[A] The sizes listed in Table 4 are those commercially available sizes used by the gas industry.
[B] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.
[C] The DR shown are designations commonly accepted by the gas industry and do not calculate exactly.
[D] These wall thicknesses are minimum and are not a function of the dimension ratios.

TABLE 5 Pipe Category

Property	Test Method	Category							
		A	B	C	D	E	F	G	H
Temperature, °F (°C)	. . .	100 (38)	120 (49)	140 (60)	160 (71)	180 (82)	200 (93)	. . .	...
Hydrostatic Design Basis, psi (MPa)	D2837	400 (2.8)	500 (3.4)	630 (4.3)	800 (5.5)	1000 (6.9)	1250 (8.6)	1600 (11.0)	2000 (13.8)
Melt Index[A]	D1238	>0.5	0.2–0.5	0.01–0.3	<0.01[B]	[C]	. . .	. . .	...
Examples: CDB - At 140ºF (60ºC) the HDB is 800 psi (5.5 MPa). The approximate melt index range is 0.2 to 0.5 g/10 min for this PE pipe. DF - At 160ºF (71ºC) the HDB is 1250 psi (8.6 MPa)[A] .									

[A] The Melt Index information in this table is intended to provide guidance relating to heat fusion joining of PE materials, not for classification of materials. This property is not applicable to non-PE materials or to mechanical fittings. See 7.5.
[B] Typically melt flow measured under condition 190/21.6 is less than 4.01 g/10 min.
[C] When a PE pipe or fitting is marked per 7.2 or 7.5 with the letter "E," it affirms that the manufacturer has verified the applicability of generic fusion joining with their products in accordance with PPI TR-33 and PPI TR-41 by joining to itself and to other "E" materials and testing the joints in accordance with applicable regulations. However, qualification of joining procedures by operators in accordance with applicable regulations may still be required. Information about manufacturers who have verified PPI TR-33 and PPI TR-41 generic fusion joining with their products is found in PPI TR-33 and PPI TR-41. Consult PPI and the manufacturer for additional information.

5.8 *Elevated Temperature Service*—piping materials intended for use at temperatures above 100°F (38°C) shall have the PPI hydrostatic design basis (HDB) determined at the specific temperature in accordance with Test Method D2837. The 100 000-h intercept (long-term strength) shall be categorized in accordance with Table 5 and be listed as the "hydrostatic design basis of XXX psi at XXX °F (C°) for (compound name)."

NOTE 14—Many design factors for elevated temperature service cannot be covered in this specification. Users should consult applicable codes for limitations on pertinent maximum temperatures.

NOTE 15—In the absence of an HDB established at the specified temperature, the HDB of a higher temperature may be used in determining a design pressure rating at the specified temperature by arithmetic interpolation.

5.9 *HDB Validation for PE Pipe*—The 73°F (23°C) Hydrostatic Design Basis (HDB) of PE pipe shall be validated by the pipe producer using the PE validation procedure as outlined in Test Method D2837. For MDPE materials, the HDB of 1250 psi shall be validated; for HDPE materials, the HDB of 1600 psi shall be validated.

5.10 *Resistance to Rapid Crack Propagation (RCP) for Pipe*—Additional testing for resistance to RCP is required when the wall thickness of the pipe being produced in accordance with this standard exceeds that of the pipe used to establish the resistance to RCP for the PE compound. In these circumstances, additional testing for resistance to failure by RCP in accordance with the procedures set forth in ISO 13477 (S4 Test) or ISO 13478 (Full Scale Test (FST)) shall be conducted. In cases of conflict, the RCP results of ISO 13478 shall apply. The data obtained shall be made available upon request without limitations on disclosure, and shall not subsequently be subject to disclosure limitations when used by others.

NOTE 16—The requirements and testing for resistance to RCP specified in this specification do not provide information for all possible conditions of use. The user should consult with the manufacturer and other appropriate sources such as resin suppliers, research, academia, etc., to determine that the RCP resistance provided by the pipe producer is sufficient for the intended use.

5.11 *Inside Surface Ductility for Pipe*—The inside surface of pipe shall be ductile as shown by testing in accordance with 5.11.1, 5.11.2, and 5.11.3. Before testing, specimens shall be conditioned in accordance with Practice D618 for 40 h at 73.4 ± 3.6°F (23 ± 2°C) and 50 % relative humidity.

NOTE 17—ID ductility testing may also be conducted for quality control purposes, however, there is no known data that identifies one test as inferior, equal, or superior to the others, therefore, results from one test should not be evaluated against the results from either of the other two tests.

5.11.1 *Bend-back Test Method:*

5.11.1.1 From the pipe, squarely cut a ring of pipe with a minimum width of 1¼ (32 mm). The entire wall thickness may be tested, or material may be removed from the OD surface of the pipe, while maintaining an undisturbed ID surface, to produce a ring with ⅜-in. (9.5-mm) wall thickness.

NOTE 18—The ring may be tested in its entirety, or may be cut into

representative sectors to produce bend-back test specimens.

5.11.1.2 In a well-lit area at 73.4 ± 3.6°F (23 ± 2°C) perform the following procedure within 5 min: *(a)* Bend the specimen inside-out (reverse-bend so that the pipe ID surface is on the outside surface of the bent specimen). *(b)* Using an apparatus such as a vise or other suitable bending equipment, close the legs of the specimen together. When the specimen legs are closed together, the top of the bend-back specimen shall protrude 1 to 1¼ in. (25 to 32 mm) or two wall thicknesses, whichever is greater, above the point of closure (jaws). *(c)* With the unaided (naked) eye, visually examine the protruding reverse-bent pipe ID surface for signs of brittle cracking or crazing.

5.11.1.3 Any indication of brittle cracking or crazing indicates failure.

5.11.2 *Elongation-at-Break Test Method* :

5.11.2.1 Five Test Method D638 Type IV specimens cut in the longitudinal direction from locations equally spaced around the circumference of the pipe shall be tested in accordance with Test Method D638 at a cross-head separation speed of 2 in. (50.8 mm) min, and at 73.4 ± 3.6°F (23 ± 2°C). If the specimen thickness must be reduced by machining, the pipe ID surface shall be left unaltered.

NOTE 19—If the specimen thickness is reduced, the machined side of the specimen must be smooth and the thickness of the specimen in the gage length must be uniform. Surface cuts or scratches and nonuniform thickness in the specimen gage length can detrimentally affect test results.

5.11.2.2 The percent elongation at break for each test specimen shall exceed 400 %.

5.11.3 *Thermal Stability Test Method*—Specimens of the pipe inside wall surface not more than 0.005 in. (0.13 mm) thick shall demonstrate a minimum induction temperature of 428°F (220°C) when tested in accordance with the Test Method for Thermal Stability in Specification D3350.

5.12 *Squeeze-Off*—This requirement is limited to pipe sizes, wall thicknesses, squeeze procedures, and conditions deemed suitable for squeeze-off in service by the pipe manufacturer. There shall be no leakage or visual evidence of splitting, cracking, breaking or reduction in 1000-h sustained pressure category when pipe is tested as follows:

5.12.1 Prepare six randomly selected pipe specimens in accordance with Test Method D1598 except they shall be unfilled.

5.12.2 The squeeze-off shall be effected at the mid-point of the test specimen, 90° to the point of the measured minimum wall thickness. Close the squeeze bars to the gap stop in Specification F1563 and hold in constraint for 4 h. Remove squeeze bars and reround pipe by closing squeeze bars at a point 90° from the squeeze area.

5.12.3 Immediately upon removal of the squeeze-off tool, fill the specimens with ambient temperature water, that is, 67 ± 10°F (19.4 ± 5.6°C), condition, and test in accordance with 6.6.

5.13 *Joints:*

5.13.1 *Heat Fusion:*

5.13.1.1 Heat fusion joints of thermoplastic pipe and fittings shall be made in accordance with Practice F2620 and the user's written procedure.

5.13.1.2 PE butt fusion joining shall be between components (pipes, fittings, or valves) having the same SDR or DR. Butt fusion between unlike SDR or DR components shall be allowed only if it has been demonstrated that long term performance is not adversely affected. The minimum requirement to demonstrate long term performance shall be the validation procedure for PE in Test Method D2837. The Hydrostatic Design Basis (HDB) of the PE material shall be validated using specimens containing butt fusion joints resulting from different SDRs or DRs. Pipe/pipe joints of the given PE material that pass shall validate pipe/pipe, pipe/fitting, or fitting/fitting joints of the same SDR ratio for that PE material.

5.13.2 *Mechanical*—Mechanical fittings shall be installed in accordance with the user's written procedures and the fitting manufacturer's installation instructions. The joint shall be tested in accordance with the specific design category as outlined in 6.10.

5.13.3 *Electrofusion*—Electrofusion joints shall be made in accordance to user's written procedures and the fitting manufacturer's installation instructions.

5.14 *Fittings:*

5.14.1 Socket-type fusion fittings shall meet the requirements of Specification D2683.

5.14.2 Butt-type fusion fittings shall meet the requirements of Specification D3261.

5.14.3 Electrofusion fittings should meet the requirements of Specification F1055.

5.15 *PE Valves*—All PE gas valves shall meet the requirements of ANSI Standard B 16.40.

5.16 *Excess Flow Valves*—All excess flow valves shall meet the requirements of Specification F2138.

6. Test Methods

6.1 *General*—The test methods in this specification cover plastic pipe and fittings to be used for gas distribution. Test methods that are applicable from other specifications will be referenced in the paragraph pertaining to that particular test.

6.2 *Sampling*—Take a representative sample of the pipe and fittings sufficient to determine conformance with this specification. About 40 ft (12 m) of pipe is required to perform all the tests prescribed. The number of fittings required varies, depending upon the size and type of fitting. A sampling plan shall be agreed upon by the purchaser and the manufacturer (see Practice D1898).

6.2.1 *Pipe Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

6.3 *Conditioning*—For those tests where conditioning is required or unless otherwise specified, condition the specimens prior to testing for a minimum of 1h in water or 4h in air at 73.4 ± 3.6°F (23 ± 2°C).

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

6.5 *Dimensions and Tolerances:*

6.5.1 *Pipe*—Any length of pipe is used to determine the dimensions. Coiled pipe shall be measured in the natural springback condition, unless specified otherwise.

6.5.1.1 *Diameter*—Measure the diameter of the pipe in accordance with Test Method D2122. The average outside diameter for nonroundable pipe is the arithmetic average of the maximum and minimum diameters at any cross section on the length of the pipe. For roundable pipe, out-of-roundness tolerance applies to measurements made while the pipe is rounded with the manufacturer's recommended equipment. Measure out-of-roundness within one-half pipe diameter or 2 in. (50 mm), whichever is closer, of the rounding equipment. See Test Method D2122 for definitions of nonroundable and roundable pipe.

(1) The pipe surface shall be free of gross imperfections such as, deep scratches, grooves, or high or low (flat) spots around the pipe circumference.

NOTE 20—Excessive out-of-roundness may be caused by manufacturing irregularities around the circumference of the pipe, such as deep scratches, gouges, flat spots, and high spots. Such defects could detrimentally affect joining. To simulate field joining of roundable pipe, out-of-roundness is checked by fitting a rounding device on the pipe, then measuring diameter.

6.5.1.2 *Wall Thickness*—Make a minimum of six measurements at each cross section in accordance with Test Method D2122.

6.5.1.3 *Wall Thickness Eccentricity Range*—Measure in a manner such that the maximum, A, and the minimum, B, wall thickness at single points of each cross section measured are obtained. Calculate the wall thickness eccentricity range, E, in percent for each cross section as follows:

$$E = [(A - B)/A] \times 100 \quad (1)$$

6.5.1.4 *Length*—Measure pipe length and other linear dimensions with a steel tape or other device, accurate to ±1⁄32 in. (±1 mm) in 10 ft (3 m).

6.5.2 *Fittings*—Measure the dimensions of fittings in accordance with Test Method D2122.

6.5.3 *Ovality*—Determine percent ovality in accordance with Test Method D2122.

6.6 *Sustained Pressure Test:*

6.6.1 Select six test specimens of pipe at random, condition at the standard laboratory test temperature and humidity, and pressure test in accordance with Test Method D1598.

6.6.1.1 Test specimens shall be prepared so that the minimum length of pipe on each side of the fitting is equal to 5 times the diameter of the pipe but in no case less than 12 in. (304 mm) for sizes less than 6 in. For sizes 6 in. and larger, the minimum length shall be equal to 3 times the diameter or 30 in. (762 mm), whichever is shorter.

6.6.1.2 Pressures used shall be calculated using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress, whichever is greater. The test fiber stress shall be 90 % of the hydrostatic design basis (HDB).

NOTE 21—Air, methane, or nitrogen may be substituted for water as the test medium.

6.6.2 Maintain the specimens at the pressures required, held to ±10 psi (0.07 MPa), for a period of 1000 h at the test temperature ±3.6°F (±2°C) as specified in 6.6.1.

6.6.3 Failure of two of the six specimens tested shall constitute failure in 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 in the test. Evidence of failure of the pipe shall be as defined in Test Method D1598.

6.7 *Minimum Hydrostatic Burst Pressure (Quick Burst)*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599. Pressures shall be calculated using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress, whichever is greater.

6.8 *Apparent Tensile Properties*—The procedure and test equipment shall be as specified in Test Method D2290, Procedure B. The speed of testing shall be 0.5 in. (12.7 mm)/min. Cut "ring" specimens from pipe. Test a minimum of five specimens. This method is applicable to all pipe of nominal ¾-in. (19.0-mm) outside diameter and larger.

6.9 *Chemical Resistance*—Determine the resistance to the following chemicals in accordance with Test Method D543. Where available, the test specimen shall be a ring 2 in. SDR 11 pipe cut to the ring dimensions specified in 6.8. For materials that are not readily available as 2 in. SDR 11 pipe, the test specimen shall be a plaque of material ¼ by 2 by 4 in. (6.3 by 50.8 by 101.6 mm) with a 1 in. (25.4 mm) wide reduced section.

Chemicals	Concentration (% by volume)
Mineral oil (USP)	100
Tertiary-butyl mercaptan	5 in mineral oil
Antifreeze agents (at least one shall be used):	
Methanol, or	100
Ethylene glycol	100
Toluene	15 in methanol

Test five specimens with each chemical. Weigh the specimens to the nearest 0.005 g and completely immerse them in the chemicals for 72 h. On removal from the chemicals, wipe the specimens with a clean dry cloth. Condition in air for 2 to 2¼ h and reweigh. Calculate the increase in weight to the nearest 0.01 % on the basis of initial weight. Test the specimen in tension in accordance with 6.8 within ½ h after weighing. Examine the weight and apparent tensile strength of each specimen for conformance to the requirement in 5.5. (**Warning—**Because of the possible toxicity of these reagents, refer to the Material Safety Data Sheet on each of these reagents before using or handling them.)

6.10 *Categorization of Mechanical Joints*—The following test methods provide a uniform procedure for qualification or categorization of mechanical joints using short term pullout resistance tests and burst tests. The mechanical joint categories and test methods are as follows:

6.10.1 *Category 1*—A mechanical joint design that provides a seal plus a resistance to a force on the pipe end equal to or greater than that which will cause a permanent deformation of the pipe.

6.10.1.1 The apparatus and report shall be as specified in Test Method D638. The test shall be conducted at ambient

temperatures, that is, 67 ± 10°F (19.4 ± 5.6°C). The speed of the testing shall be 0.2 in. (5 mm)/min ±25 %. Five specimens shall be prepared following the manufacturer's published installation instructions. Length of the specimens shall be such that the unreinforced distance between the grip of the apparatus and the end of the stiffener is at least five times the nominal outside diameter of the pipe size being tested. Apply a load until permanent deformation (yield) occurs in the unreinforced area of the piping.

6.10.1.2 Results obtained from the above method pertain only to the specific outside diameter, wall thickness, and compound of the piping used in the test and specific fitting design tested.

NOTE 22—The ability to restrain pipe to its yield as specified above does not guarantee that a properly installed joint will prevent pullout under actual long-term field conditions. Joints that cannot pass this test would be expected to pullout under actual long term field conditions. To date, this test is the best available for disqualifying unsound joints.

6.10.2 *Category 2*—A mechanical joint design that provides a seal only (see Appendix X1.5.5). A mechanical joint designed for this category excludes any provisions in the design or installation of the joint to resist any axial pullout forces; therefore, tensile tests are not required.

6.10.2.1 The test assembly shall meet the burst test requirements of 5.5 when tested in accordance with Test Method D1599 with end closures designed in accordance with Test Method D1599.

6.10.3 *Category 3*—A mechanical joint design that provides a seal plus a pipe restraint rating equivalent to the anticipated thermal stresses occurring in a pipeline (see Appendix X1.4). This category has a manufacturer's rated pipe end restraint less than the value required to yield the pipe as outlined in 6.10.1 (Category 1).

6.10.3.1 The procedures and testing shall be the same as outlined in 6.10.1 (Category 1) except the test tensile values shall meet the rated values published by the mechanical fitting manufacturer.

7. Marking

7.1 *Pipe*—All required marking shall be legible, visible, and permanent. To ensure permanence, marking shall be applied so it can only be removed by physically removing part of the pipe wall. The marking shall *(1)* not reduce the wall thickness to less than the minimum value for the pipe, *(2)* not have any effect on the long-term strength of the pipe, and *(3)* not provide leakage channels when elastomeric gasket compression fittings are used to make the joints. These marking shall consist of the word GAS, the designation ASTM D2513, the manufacturer's name or trademark, the nominal pipe size including the sizing system used (IPS, CTS, or OD), DR or minimum wall thickness, material designation, and date of manufacture.

NOTE 23—Earlier editions of Specification D2513 included PE material designations PE2406 and PE3408. Changes to Specification D3350 led to changes in the PE material designation codes that resulted in the PE material designations PE2406 and PE3408 being superceded by newer material designations. Additionally, OPS 49 CFR Part 192 may not reference the most current version of D2513 and as a result may require marking with material designation codes that are no longer included in this Specification. For these reasons two material designations may be present. For example, PE4710 pipes were previously described as PE3408 pipes and may be marked PE3408/4710. Similarly PE2708 pipes were previously described as PE2406 pipes and may be marked PE2406/2708.

7.1.1 In addition to 7.1, the pipe marking shall include a coding that will enable the manufacturer to determine the location of manufacture, pipe production and resin lots, and any additional information which is agreed upon between the manufacturer and purchaser. The manufacturer shall maintain such records for fifty years or for the design service life of the pipe, whichever is longer.

7.1.2 All the markings in 7.1 and 7.1.1 shall be repeated at intervals not exceeding 2 ft (0.61 m). For indented printing, either the indented print line shall be in a color that contrasts with that of the pipe, or a separate print line shall be in a color that contrasts with the pipe. When color is applied such as with color stripes, a color shell or solid color pipe, yellow color shall be used.

7.2 Pipe intended for natural gas service at elevated temperatures greater than 73°F (23°C) shall be marked with additional code letters from Table 5 (the first code letter to identify the temperature of pressure rating, the second code letter to identify HDB at highest rated temperature, and the third code letter to identify the melt index).

NOTE 24—The non-mandatory, preferred order for all the items required in the print line in the marking sections 7.1 and 7.2 are:
(1) Pipe size including sizing system (IPS, CTS or OD),
(2) SDR (DR) or minimum wall thickness,
(3) Manufacturer's name or trademark,
(4) GAS,
(5) Pipe material designation code,
(6) Elevated temperature code from Table 5,
(7) ASTM D2513,
(8) Manufacturer's lot code (includes date of manufacture in some cases), and
(9) Additional information, including date of manufacture, coil number sequential footage, third party certification mark etc.
Example: 2 in. IPS SDR 11 MANUFACTURER NAME GAS PE 2708 CEC ASTM D2513 LOT CODE INFO 02JAN98 coil #506.

7.3 PE pipe shall be marked with the melt index category in accordance with Table 5 in addition to the marking requirements of 7.1.

7.4 Markings for potable water, sewer, reclaimed water, communications or electrical use are prohibited.

7.5 *Fittings*—Fittings shall be marked D2513, as well as with the applicable fitting specification. All fittings shall be marked on the body or hub. The markings shall consist at least of the manufacturer's name or trademark, or both, the size, the symbol for the type of material, and the three-letter code from Table 5 (as described in 7.2). In addition, the fittings markings shall include code that will enable the manufacturer to determine the date of manufacture, the location of manufacture, fitting production and resin lots, and any additional information which may be agreed upon between the manufacturer and purchaser. The manufacturer shall maintain such records for 50 years or for the design service life of the fittings, whichever is longer.

NOTE 25—7.5 is applicable to fusion type fittings only. The marking requirements in 7.5 are not applicable to mechanical fittings.

7.6 All PE pipe, tubing, and fusion fittings meeting the requirements of this specification for gas distribution systems shall be marked with the 16-character gas distribution component tracking and traceability identifier in accordance with Specification F2897. The 16-character code shall be expressed in alphanumeric format and Code 128 bar code format with a minimum bar thickness value of 0.005 in. or an alternative 1D or 2D bar code symbology as agreed upon between manufacturer and end user. All fittings shall have the 16-character codes marked or affixed to the product, product packaging, or any manner agreed upon between manufacturer and end user.

8. Quality Assurance

8.1 When the product is marked with this designation, D2513, 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

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 performance of all inspection and test requirements specified herein. The producer shall 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 practices 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.

ANNEXES

A1. IN-PLANT QUALITY CONTROL PROGRAM FOR PE PLASTIC PIPE AND FITTINGS UP TO AND INCLUDING 12 IN. NOMINAL DIAMETER

A1.1 Quality Control

A1.1.1 The following in-plant quality control program shall be used to assure compliance with this specification. The pipe and fittings producers shall maintain records on all aspects of this program and supply these to the purchaser, if requested.

A1.1.2 *In-Plant Quality Control Test Methods*—Test methods other than those specified in Section 6 are used as long as they provide equivalent results. In case of disagreement, those test methods in the applicable ASTM standard shall be used.

A1.2 Pipe Tests

A1.2.1 *Material and Extrusion Process Qualification*—Sustained pressure tests shall be made on one pipe size in the range of 2 in., or less, and on one pipe size in the range of 2½ in., or greater. This test shall also be made on pipe from each particular commercial plastic resin initially, and at least twice a year thereafter for material and extrusion process qualification and not as a quality control on the product. This test shall be made in accordance with A1.2.1.1 using any of the test conditions in Table A1.1.

A1.2.1.1 *Elevated Temperature Sustained Pressure Test Method*—Select six random specimens produced at the manufacturer's facility using the Table A1.1 polyethylene pipe material designation code. Test these pipe samples in accordance with Test Method D1598 using water as the internal test medium.

A1.2.1.2 Passing results are *(1)* non-failure for all six specimens at a time equal to or greater than the Table A1.1 "minimum average time before failure," or *(2)* not more than one ductile specimen failure and the average time before failure for all specimens shall be greater than the specified "minimum average time before failure" for the selected Table A1.1 Condition. If more than one ductile failure occurs before the Table A1.1 "minimum average time before failure," it is permissible to conduct one retest at a Table A1.1 Condition of lower stress and longer minimum average time before failure

TABLE A1.1 Elevated Temperature Sustained Pressure Test Requirements[A]

Condition	Test Temperature °F (°C)	Pipe Material Designation Code PE 2708		Pipe Material Designation Code PE 4710	
		Test Temperature Hoop Stress[A], psi (kPa)[B]	Minimum Average Time Before Failure, Hours	Test Pressure Hoop Stress[A], psi (kPa)[B]	Minimum Average Time Before Failure, Hours
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A] Calculate internal test pressure in accordance with :

$$P = \frac{2S}{\left(\frac{Do}{t} - 1\right)}$$

Where:

P = test pressure, psig (kPa);
S = test pressure hoop stress, psi. (kPa)
D_O = measured outside diameter, in. (mm)
t = measured minimum wall thickness, in (mm)

[B] Test temperature tolerance ±3.6°F (±2°C). Test pressure tolerance ± 5psi (±35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa.

for the material designation except that for Table A1.1 Condition 6 no retest is permissible. Brittle failure of any specimen in the test sample when tested at Table A1.1 Condition 1 through 6 constitutes failure to meet this requirement and no retest is allowed.

A1.2.1.3 *Provision for retest (if needed)*—The retest sample shall be six specimens of the same pipe or tubing size and material designation from the same time frame as the test sample per A1.2.1.2. For the retest, any specimen failure before the "minimum average time before failure" at the retest condition of lower stress and longer minimum average time before failure constitutes failure to meet this requirement.

NOTE A1.1—Table A1.1 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE 4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) × ((1200 – 200) / (750 – 640)) = 927).

A1.2.2 *Product Quality Control* (Note A1.2) The tests in Table A1.2 shall be made per size per extrusion die at the denoted frequencies and the test results recorded and filed for inspection on request.

NOTE A1.2—When the pipe fails to meet this specification in any test, additional tests shall be made on the pipe produced back to the previous acceptable result to select the pipe produced in the interim that does pass the requirement. Pipe that does not meet the requirement shall be rejected.

NOTE A1.3—For pipe sizes above 4-in. nominal diameter, the quick burst test (Test Method D1599) may be replaced by the Apparent Ring Tensile Strength Test (Test Method D2290) if agreed to between the purchaser and the manufacturer.

TABLE A1.2 Product Quality Control Tests

Property	Frequency
Diameter	Once every hour or every coil, whichever is less frequent
Wall thickness	Once every hour or every coil, whichever is less frequent
Ring tensile or burst pressure	Testing shall commence at the beginning of production of a particular pipe or tubing size, and shall continue weekly thereafter. If production is interrupted, testing shall recommence after the interruption as though at the beginning of production.

A1.3 Fittings Tests[10]

A1.3.1 The fittings tests listed in the following subparagraphs shall be conducted at the frequencies indicated.

NOTE A1.4—When any fitting fails to meet the requirements of this specification, or the applicable referenced fitting specification, additional tests should be made on fittings produced back to previous acceptable result to select the fittings produced in the interim that do meet the requirements. Fittings that do not meet the requirements shall be rejected.

A1.3.2 *Dimensions:*

A1.3.2.1 *Socket Fittings:*

(a) Socket Entrance, Bottom and Minimum Internal Diameters—Once an hour or one out of ten fittings, whichever is less frequent.

(b) Wall Thickness—At the beginning of each production setup for each cavity.

A1.3.2.2 *Butt Fusion Fittings:*(a) *Outside Diameter and Wall Thickness*—Once an hour or one out of ten fittings, whichever is less frequent.

A1.3.3 *Other Tests:*

[10] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F17-1018.

A1.3.3.1 *PE Fittings*—At the start of each production run, whenever production conditions have changed, or when the resin lot is changed, but not less frequently than once per 500 fittings thereafter, the following tests shall be made:

(a) The knit line strength for at least one fitting from each cavity shall be demonstrated by one of the following tests:

[1] Crushing a fitting, or a portion of a fitting, in a manner that applies load in the direction normal to the knit line. See Note A1.5.

[2] Apparent tensile strength tests of a ring cut from a fitting, with the load oriented normal to the knit line. See Note A1.6.

[3] Burst testing of the fitting. See Note A1.6.

(b) The integrity of at least one part from each mold cavity shall be verified, using a method selected by the manufacturer as appropriate for this specific product and process.

NOTE A1.5—Separation in the knit constitutes a failure.

NOTE A1.6—In tests 2 and 3 the strength requirements shown in the annexes must be met.

A2. IN-PLANT QUALITY CONTROL PROGRAM FOR 14-IN. AND LARGER DIAMETER POLYETHYLENE PIPE

A2.1 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.

A2.2 Lengths of pipe that are shorter than standard shipping lengths are butt-fused to produce standard lengths. Such build-up lengths must otherwise meet all of the product requirements of this specification.

A2.3 Manufacturers of pipe shall conduct such other quality control tests as are appropriate to their manufacturing operations that will provide assurance that the product requirements of Section 5 will be met in place of the actual performance of the specified tests.

NOTE A2.1—The pressure tests required under product requirements are tests for performance. These tests are not adaptable to in-plant quality control. Quality control tests have not been standardized because the requirements for such tests vary substantially from one manufacturing plant to another.

APPENDIX

X1. DESIGN CONSIDERATIONS

X1.1 General

X1.1.1 The design of a PE piping system for natural gas service must include consideration of the combined effects of time, internal and external stress, and environment as an overall basis for selecting a specific kind and size of PE pipe. The design stress for PE pipe used for distribution of natural gas and petroleum fuels is regulated by the U.S. Department of Transportation as published in OPS 49 CFR Part 192 of the Code of Federal Regulations.

X1.2 Design Equations

X1.2.1 *Relationship Between Pipe Stress and Pressure*—The following expression is used to relate stress, pressure, pipe size, and wall thickness:

$$P = 2S/(DR - 1) \quad \text{(X1.1)}$$

or

$$2S/[(D_o/t) - 1]$$

where:

S = stress in the circumferential or hoop direction, psi (MPa),
P = internal pressure, psig (MPa),
DR = dimension ratio,
D_o = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

X1.2.2 The following expression can be used to determine the burst pressure or sustained pressures needed in testing:

$$P_b = 2S_y/(DR - 1) \quad \text{(X1.2)}$$

where:

P_b = burst pressure, psig (MPa),
S_y = yield stress, psi (MPa), and
DR = dimension ratio.

$$P_s = 2S_f/(DR - 1) \quad \text{(X1.3)}$$

where:

P_s = sustained pressure, psig (MPa),
S_f = fiber stress psi (MPa), and
DR = dimension ratio.

X1.2.3 *Relation between Hydrostatic Design Basis (HDB) and Hydrostatic Design Stress (HDS)*—The *HDS* is determined by multiplying the *HDB* by a design factor, *f*. The design factor, *f*, has a value less than 1.0.

$$HDS = (HDB)(f) \quad \text{(X1.4)}$$

NOTE X1.1—The actual choice of design factor for a given installation must be reviewed by the design engineer taking into account federal, state, and local code requirements. For example, the design factor for gas pipelines under the jurisdiction of the Department of Transportation is 0.32.

NOTE X1.2—In some countries, the ISO MRS method is used to

determine the maximum operating pressure (MOP) using the formula MOP = 2 MRS/(DR-1) C, which incorporates the pipe DR (dimension ratio), the MRS (minimum required strength) of the pipe material as determined by ISO 9080 and ISO 12162 and the design coefficient (C). Guidance on selection for the value of C is provided in the following references: ISO 4437, ISO 12162, and PPI TR-9.

X1.3 Design Stress and Internal Pressure for Natural Gas

X1.3.1 The design stresses for natural gas pipe are based on the hydrostatic design basis at 73°F (23°C) obtained in accordance with Test Method D2837. The test medium should be natural gas or simulated natural gas except that water may be used where previous tests have shown that for the particular type of plastic, water and natural gas give essentially the same test results. The hydrostatic design basis of the PE presently included in the applicable ASTM specifications are as follows:

PE Pipe Material Designation	Hydrostatic Design Basis at 73°F (23°C), psi (MPa)
PE2708	1250 (8.6)
PE4710	1600 (11.0)

X1.3.2 The design stresses for natural gas at service temperatures above 73°F (23°C) should be based on hydrostatic design basis of the pipe that are applicable for the particular use temperature.

X1.3.3 The design stress for PE pipe for fuel gases other than natural gas should be based on hydrostatic design basis categories that have been established with the intended gas as the pressurizing medium (see X1.7.2 for information on the effect of common LPG fuels on the long-term strength of PE pipes).

NOTE X1.3—Water may be used in lieu of a particular fuel gas where previous tests have shown that the results obtained with water are equivalent.

X1.3.4 The design stresses for natural gas are obtained by multiplying the hydrostatic design basis by design factors or service factors according to the class of location as described in Chapter IV of the American National Standard Code for Pressure Piping ANSI B31.8, or, for gas operators in the United States, Subpart C of the Minimum Federal Safety Standards for Transportation of Natural and Other Gas by Pipeline, OPS 49 CFR Part 192.

X1.3.5 For liquefied petroleum gas (LPG) applications, a maximum operating pressure of 30 psig (206 kPa) is recommended in NFPA 58 by the members of the National Liquefied Petroleum Gas Association. Liquefied petroleum gas has a higher condensation temperature than does natural gas; this maximum pressure is recommended to ensure that plastic pipe is not subjected to excessive exposure to LPG condensates. (See X1.7.1.)

X1.4 Thermal Stress

X1.4.1 Calculate the longitudinal stress (theoretical) induced in a pipe member between fixed points as follows:

$$S = E \times C \times \Delta t \quad \text{(X1.5)}$$

where:

S = stress, psi (MPa),
E = modulus of elasticity, psi (MPa), instantaneous, at 73°F (23°C),
C = coefficient of expansion, in./in./°F, (mm/mm/°C), and
Δt = maximum temperature minus minimum temperature, °F (°C).

X1.4.1.1 The measured stress has been determined to be less than that calculated. This difference is caused by the stress relaxation in viscoelastic materials.

X1.4.2 Calculate the theoretical force sustained at the fixed points (typically joints) in a pipe member as follows:

$$F = S \times A \quad \text{(X1.6)}$$

where:

F = force, lbf (N),
S = stress, psi (MPa), and
A = cross-sectional pipe wall area, in.^{2} (mm^2).

X1.4.3 Calculate pipe contraction in unrestrained pipe caused by a reduction in temperature as follows:

$$\Delta L = k \times L \times C \times \Delta t \quad \text{(X1.7)}$$

where:

ΔL = change in length,
k = 1000 for ΔL (mm), L (m), C (°C^{-1}), Δt (°C), or
k = 12 for ΔL (in.), L (ft), C (°F^{-1}), Δt (°F),
L = original length,
C = coefficient of linear expansion, and
Δt = temperature change.

X1.5 Installation Procedure

X1.5.1 It is recognized that certain minimum requirements exist for the support of earth loads from backfill and other external forces. Proper installation techniques can be used with flexible conduit (as defined by Marston and Spangler (**2**)) to support relatively large earth loads without excessive deflection by mobilizing lateral passive soil forces. Proper installation technique ensures that the necessary passive soil pressure at the side of the pipe will be developed and maintained. It is also recognized that internal pressures may be valuable in minimizing the deflection caused by earth loads. Installation procedures described in Recommended Practice D2774, ANSI B31.8, and the AGA Plastic Pipe Manual for Gas Service[11] are recommended.

X1.5.2 Unrestrained PE pipe expands and contracts from thermal change significantly more than metallic pipe. This ratio may be of the magnitude of ten to one. Typical coefficients of thermal expansion for unrestrained pipe for PE is 9.0×10^{-5} (in./in.)/°F 24.30 (mm/mm)°C.

X1.5.2.1 Mains and service lines installed by insertion are considered to approximate unrestrained conditions inside the casing pipe except at end connections. Direct-burial pipe is considered to be partially restrained by passive soil pressures except in the vicinity of joints.

X1.5.3 Internal pressure, earth settlement, ground movement, and thermal contraction impose stresses on the pipe

[11] Available from American Gas Association (AGA) 400 North Capitol Street, NW Suite 450 Washington, DC 20001, http://www.aga.org.

that can be transmitted to joints. These stresses are additive. Installation practices should reflect the need for continuous support and containment of the pipe through suitable bedding and backfilling procedures. Attention should be given to all joints, particularly to transition joints between PE and metal pipe.

X1.5.4 It is desirable to have pipe joints that are as strong as the pipe itself in the longitudinal (axial) direction. Thermal fusion, and mechanical joints outlined in 6.10, Category 1 can provide such joint strength. The joint strength is a function of the assembly procedure, the design of the fitting, and the pipe material and dimensions (see X1.5.5).

X1.5.5 For those mechanical devices that are not designed to restrain the pipe against pullout forces, provisions must be made in the field to prevent pullout, keeping in mind that mechanical joints are vulnerable to the effects of internal pressure, temperature changes, earth settlement, and ground movement. A somewhat limited alternative is to use long sleeve-type fittings that permit limited movement without loss of pressure seal. Otherwise, provisions must be made in the field to prevent pullout through suitable anchoring at the joint.

X1.5.6 Plastic pipe joined with mechanical connectors that utilize a compression-type gasket must be reinforced by means of a tubular stiffener that extends at least under the section of pipe being compressed by the gasket and the gripping device (where used). The stiffener shall be nonsplit-type design to meet the performance requirements recommended by the manufacturer of the fitting in which it is used, and the joint shall meet the test requirements outlined in 6.10.

X1.5.7 Kinks found in the pipe shall be cut out. Pipe with kinks shall not be placed in service.

X1.6 Repair Considerations

X1.6.1 Repairs may be made to PE pipe under appropriate circumstances. Selection and installation considerations for the use of full encirclement band clamps are available in ASTM Guide F1025. Additional information on repair of PE pipe may be found in manufacturers' literature, the AGA Plastic Pipe Manual for Gas Service,[11] ANSI B31.8 Gas Transmission and Distribution Piping Systems, and in the ASME Guide for Gas Transmission and Distribution Piping Systems.[12]

X1.7 Environmental Effects

X1.7.1 *Natural Gas*—The natural gas of commerce consists of methane as the principal constituent with minor amounts of other gases, which can include other hydrocarbons (for example, ethane, propane, butane, pentane), inert gases (for example, nitrogen, carbon dioxide), and odorants. The long term effect of natural gas (methane, but with minor amounts of other gases) at 73°F (23°C) has been shown (**3**,**4**) to be essentially equivalent to that of water at 73°F (23°C) for PE pipe.

X1.7.2 *Other Fuel Gases*—In accordance with this specification, PE materials must have not less than a 1250 psi HDB for 73.4°F, for methane. It has been shown (**5**, **6**, and **7**) that aliphatic gaseous fuels of higher molecular weights than methane (natural gas) somewhat reduce the long-term strength of PE pipe materials compared to when using methane or water as the pressurizing medium. The reduction in PE's long-term strength caused by gaseous propane, propylene and butane is modest, well under 20 %. On this basis one report (**5**) considers an HDB of 1000 psi, for 73.4°F, as a reasonable and conservative design basis for PE piping materials intended for LPG fuel gas service.

X1.7.2.1 However, it has also been shown by the above referenced studies that propane, propylene and butane, when in the liquid phase, can cause a greater reduction in long-term strength, up to 40 %. Accordingly, the use of PE piping to convey LPG gaseous fuels should recognize this effect and the design and operation of such piping should consider the possibility for the occurrence of condensates. Extensive experience has shown that the NFPA maximum recommended operating pressure of 30 psig for LPG systems (see X1.3.4) both minimizes the possible occurrence of condensates and gives adequate consideration of the effect of LPG fuels on the long-term strength of PE piping.

X1.7.2.2 It has been reported (**8**,**9**) and (**10**), that during the heat fusion joining of PE piping that has been in service conveying fuel gases that consist of, or that include heavier hydrocarbons, the PE surfaces being heated in preparation for fusion sometimes exhibit a *bubbly* appearance. This bubbling is the result of the rapid expansion (by heat) and passage of absorbed heavier hydrocarbon gases through the molten material. Heat fusion (butt, socket, saddle, or electrofusion) joint strength may be reduced by the presence of the heavier hydrocarbons. Pimputkar et al (**8**) conclude that for a system operating at 50psi and conveying a mixture of as high as 16 volume percent in methane the propane concentration in PE will be under 0.2 percent, sufficient to sometimes show some bubbling, but not high enough to effect any significant degradation in fusion strength. However, if the concentration of propane in PE exceeds 0.2 percent, there is the risk of a rapid and large drop in fusion strength. Field tests to verify the level of contamination and subsequent degradation of joint strength are not currently available. Therefore, in the case of PE pipe that has previously been installed in these types of services, one should use mechanical fittings to join or repair the pipe.

NOTE X1.4—PPI Technical Report TR 22–88 (**5**) lists maximum operating pressures for various minimum operating temperatures at which condensates will not form in LPG systems in which the primary fuels are propane and butane.

[12] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

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(2) D1603 Test Method for Carbon Black Content in Olefin Plastics[2]

(3) D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle Furnace Technique[2]

(4) D4883 Test method for density of Polyethylene by the Ultrasound Technique[2]

(5) ISO 11922–1 Thermoplastics pipes for the conveyance of fluids–Dimensions and tolerances—Part 1: Metric series[6]

(6) PPI TR-4 Hydrostatic Design Bases and Maximum Recommended Hydrostatic Design Stresses for Thermoplastic Piping Materials[7]

(7) National Fire Protection Association: NFPA 54,Storage and Handling Liquefied Petroleum Gases[8]

SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (D2513 – 16) that may impact the use of this standard. (Approved December 15, 2016.)

(1) Revised 6.6.1.2.

Committee F17 has identified the location of selected changes to this standard since the last issue (D2513 – $14^{\varepsilon 1}$) that may impact the use of this standard. (Approved December 1, 2016.)

(1) Revised 4.10.1.