Designation: F3123 – 15

StandardSpecification for Metric Outside Diameter Polyethylene (PE) Plastic Pipe (DR-PN)[1]

This standard is issued under the fixed designation F3123; 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 metric outside diameter polyethylene (PE) pipe made from polyethylene compound that qualifies for MRS, HDB and HDS ratings and for PE100 and PE4710 designations. Included are requirements for polyethylene compound, workmanship, dimensions, short-term stress and ductility, long-term stress, marking, quality assurance and verification of joining.

1.1.1 Polyethylene pipe in accordance with this specification is intended to be compatible with nominal diameters and nominal pressures in accordance with ISO 161-1 and wall thickness in accordance with ISO 4065.

1.2 Pipes produced under this specification are intended for the pressure or non-pressure conveyance of liquid or gaseous media. Pipes produced under this specification are not intended as enclosures for electrical or communications components. See Appendix X1.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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:*[2]

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1435 Practice for Outdoor Weathering of Plastics
D1505 Test Method for Density of Plastics by the Density-Gradient Technique
D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1603 Test Method for Carbon Black Content in Olefin Plastics
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
F412 Terminology Relating to Plastic Piping Systems
F905 Practice for Qualification of Polyethylene Saddle-Fused Joints
F1056 Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings
F1290 Practice for Electrofusion Joining Polyolefin Pipe and Fittings

[1] This test method 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] 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.

F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
F2928 Practice for Specimens and Testing Conditions for Testing Polyethylene (PE) Pipe Butt Fusions Using Tensile and Hydrostatic Test Methods
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.2 *ISO Documents*[3]

ISO 161-1 Thermoplastics pipes for the conveyance of fluids—Nominal outside diameters and nominal pressures—Part 1: Metric series
ISO 4065 Thermoplastics pipes—Universal wall thickness table
ISO 9000 Quality management
ISO 9080 Plastics piping and ducting systems—Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation
ISO 12162 Thermoplastics 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 pipes for the conveyance of fluids—Determination of resistance to rapid crack propagation (RCP)—Full-scale test (FST)
ISO 16871 Plastics piping and ducting systems—Plastics pipes and fittings—Method for exposure to direct (natural) weathering
ISO 18553 Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds

2.3 *NSF International Standards:*[4]

NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials
NSF/ANSI Standard No. 61 for Drinking Water System Components—Health Effects

2.4 *PPI Documents:*[5]

TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe
TR-4 Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strength (MRS) Ratings for Thermo plastic Piping Materials or Pipe
TN-30 Requirements for the Use of Rework Materials in Manufacturing of Polyethylene Gas Pipe
Handbook of Polyethylene Pipe, Second Edition

2.5 *Other Documents:*

Guidelines for Drinking-Water Quality, Third Edition Incorporating the First and Second Addenda, Volume 1: Recommendations, World Health Organization, Geneva, 2008[6]
EU Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption[7]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *application factor, f_A, n*—a coefficient of 1 or less that accounts for estimated long-term application effects such as chemical effects of fluid media or environment, variation of external or internal temperature or stress, and installation.

3.2.2 *design stress, σ_S, n*—the quotient of MRS divided by C_{min}. Design stress is at 20°C and applicable to the conveyance of water.

3.2.3 *maximum allowable operating pressure, PFA, n*—the maximum operating pressure in bar determined by the designer/user that accounts for polyethylene compound properties, the media being conveyed and the conditions of conveyance.

3.2.4 *minimum design coefficient, C_{min}, n*—a factor from ISO 12162 having a value of 1.25 that accounts for the properties of the piping material when transporting water at 20°C.

3.2.5 *minimum required strength, MRS, n*—a property of the material in accordance with ISO 12162 that represents a classification range in MPa of the 97.5% lower confidence limit of the mean long-term strength at 20°C and 50 years.

3.2.6 *nominal pressure, PN, n*—a nominal design rating in bar for internal pressure water at 20°C, but without consideration of media other than water or conditions other than sustained internal pressure and sustained temperature.

NOTE 1—PN is a nominal design rating for sustained internal pressure for water at 20°C that provides for product comparison under specific, limited conditions. Actual allowable operating pressure (*PFA*) is determined by the designer/user in consideration of the media being conveyed and conditions of conveyance such as pressure and temperature stability or variation, installation and quality thereof, and desired degree of reliability. (See 3.2.3, X1.1, and X1.2 for additional information.)

3.2.7 *relation between dimension ratio, MRS and nominal pressure, n*—the following equation is used in this specification to relate pres sure number (*PN*), dimension ratio (*DR*), minimum required strength (*MRS*), minimum design coefficient (C_{min}), and design stress (σ_S):

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.
[4] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48105, http://www.nsf.org.
[5] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.
[6] Available from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int).
[7] Available from Publications Office of the European Union 2, rue Mercier 2985 Luxembourg LUXEMBOURG Tel: +352 2929-1 E-mail: info@publications.europa.eu.

$$PN = \frac{20}{(DR - 1)} \times \frac{MRS}{C_{min}} = \frac{20 \times \sigma_S}{(DR - 1)} \quad (1)$$

where:

PN = nominal pressure design rating, bar,
DR = dimension ratio
= D_O/t,
D_O = nominal outside diameter, mm,
t = minimum wall thickness, mm,
MRS = minimum required strength at 20°C, MPa,
C_{min} = minimum design coefficient, and
σ_S = design stress at 20°C.

3.2.8 *relation between nominal pressure and maximum allowable operating pressure, n*—the following equation is used in this specification to relate maximum allowable operating pressure (PFA) and pressure number (PN):

$$PFA = PN \times f_T \times f_A \quad (2)$$

where:

PN = nominal pressure, bar,
PFA = maximum allowable operating pressure, bar,
f_T = temperature factor, and
f_A = application factor.

3.2.9 *temperature factor, f_T, n*—a coefficient that accounts for the long term strength of the polyethylene compound at temperatures other than 20°C.

3.2.10 *lower confidence limit of the predicted hydrostatic strength, σ_{LPL}, n*—a property of the polyethylene compound in accordance with ISO 12162 that represents a stress value in MPa for the 97.5 percent lower confidence limit of the predicted hydrostatic strength at a specified temperature in °C and time in years.

4. Pipe Classification

4.1 *General*—This specification covers 32 mm through 2000 mm metric outside diameter polyethylene pipe having wall thickness in accordance with standard dimension ratios (DR 33 through DR 7.4) and nominal pressures in bar for water at 20°C (PN5 through PN25).

4.2 Pipe manufacturing and verification of compliance with the requirements of this standard are in accordance with a written quality assurance program that specifies policies and procedures for manufacturing, frequency of inspection, sampling and testing of materials and products, and policies and procedures for documenting compliance with the requirements of this specification.

5. Polyethylene Compound and Requirements

5.1 *Polyethylene Compound*—Polyethylene compound for the manufacture of pipe in accordance with this specifi cation shall be designated in accordance with PPI TR-3 as PE100 and as PE4710 ("PE100/PE4710"), and shall comply with the following requirements:

5.1.1 See Table 1.

5.1.2 Polyethylene compound shall contain sufficient antioxidant so that the minimum induction temperature shall not be less than 220°C when tested for thermal stability in accordance with Specification D3350.

5.1.3 The brittleness temperature shall not be warmer than −60°C when tested in accordance with Test Method D746.

5.1.4 The oxidation induction time at 200°C shall not be less than 20 minutes when tested in accordance with Test Method D3895.

5.1.5 The minimum nominal tensile strength at yield shall be 20.6 MPa, and the failure mode shall be ductile when determined in accordance with Test Method D638. Testing temperature shall be 23°C and the speed of testing shall be 50 mm/min. Specimens shall conform to the dimensions and requirements for Type IV in Test Method D638 with a thickness of 1.9 ± 0.2 mm. Specimens shall be either die cut or machined. The minimum elongation at break shall be 400 percent.

5.1.6 The polyethylene compound melt flow rate (high load) shall be tested in accordance with Test Method D1238, Condition 190/21.6.

5.1.7 The polyethylene compound density in accordance Specification D3350 shall be tested in accordance with Test Method D792 or Test Method D1505.

5.1.8 Black polyethylene compound shall contain 2.0–2.5 percent carbon black when pipe is tested in accordance with 6.1.2.

5.1.9 Polyethylene compound shall be stabilized against deterioration from UV exposure for not less than 18 months for color polyethylene compounds, or for not less than 180 months for black polyethylene compounds.

TABLE 1 PE100/PE4710 Polyethylene Compound Requirements

Requirement	Required Value or Value Range
MRS at 20°C, per ISO 9080, ISO 12162 and PPI TR-3,[A] MPa	≥ 10
HDB at 23ºC, per Test Method D2837 and PPI TR-3,[A,B] MPa	≥ 11.03
HDB at 60ºC, per Test Method D2837 and PPI TR-3,[A,B] MPa	≥ 6.89
HDS for water at 23°C, per Test Method D2837 and PPI TR-3,[A,B] MPa	≥ 6.89
Melt flow rate (high load) per Test Method D1238, g/10 min	>4.0 to ≤ 20[C]
Nominal natural base resin density per SpecificationD3350,[D] g/cm^3	>0.947 to ≤ 0.955
Minimum average SCG Resistance (PENT) per Test MethodF1473,[E] hr	≥ 500

[A] MRS, HDB and HDS determinations shall be listed in accordance with PPI TR-3.
[B] HDB ratings expressed in inch-pound units are standard in Test Method D2837. Per 1.3, SI units are standard herein; therefore, the SI values specified in Table 1 are the SI equivalent values per Test Method D2837. Inch-pound values for the SI equivalent values in Table 1 are 73°F = 23°C; 140°F = 60°C; 1600 pound/in^2 = 11.03 MPa; 1000 pound/in^2 = 6.89 MPa.
[C] Per 5.1.6.
[D] Per 1.7 excluding carbon black. See Specification D3350 for determination of carbon black content effects on density.
[E] SCG resistance determined in accordance with Test Method F1473 requirements for molded plaque specimens, notching per Test Method F1473 Table 1, and testing at 80°C, 2.4 MPa. Average failure time for two test specimens.

NOTE 2—UV resistance is typically determined by exposure to actual outdoor (natural sunlight) weathering in accordance with Practice D1435, or by accelerated weathering in accordance with Practice D2565 and Practice G155. Characterization of UV resistance is typically by tension testing (per 5.1.5) for an elongation at break value that is at least 50% of the elongation at break value when compared to unexposed control specimens. Studies of high density polyethylene indicate that exposure to Xenon Arc via Practice G155-A Cycle 1 gives approximately 4.4 times the acceleration of outdoor Florida exposure. Therefore approximately 2000 hours Xenon Arc testing would approximate 1-year outdoor exposure in Florida (approx. 30th degree of latitude) or about 2-years in southern Canada (approx. 50th degree of latitude). A minimum resistance to an accumulation of 3.5 GJ/m^2 per ISO 16871 represents the yearly exposure to sunlight near the 50th degree of latitude.

5.1.10 *Certification*—When required by the purchaser, polyethylene compound shall be evaluated, tested, and certified in accordance with one or more of the following standards by an accredited laboratory that is acceptable to the authority having jurisdiction. The required certification standard(s) shall be by mutual agreement between purchaser and manufacturer.

NOTE 3—Because regulatory requirements vary, it is necessary that the purchaser identify and specify the applicable certification standard(s) to the manufacturer before product purchase.

5.1.10.1 NSF/ANSI Standard No. 61.

5.1.10.2 The health effects portion of NSF/ANSI Standard No. 14.

5.1.10.3 Guidelines for Drinking Water Quality, World Health Organization, Geneva, 2008.

5.1.10.4 EU Council Directive 98/83/EC.

5.1.11 *Listing*—MRS, HDB and HDS ratings for the polyethylene compound shall be listed in accordance with PPI TR-3.

5.2 *Polyethylene Rework Material*—Polyethylene rework material for the manufacture of pipe in accordance with this specification is to be used only when blended with new polyethylene compound that complies with 5.1. Polyethylene rework material shall comply with the following requirements:

5.2.1 Polyethylene rework material shall comply with PPI TN-30 and shall be from production in accordance with this specification that complies with the melt filtration requirements of PPI TN-30.

5.2.2 The melt flow rate in accordance with Test Method D1238, Condition 190/21.6 for polyethylene rework material shall be within ±20 percent of the test value per 5.1.6.

5.2.3 The oxidation induction time at 200°C for polyethylene rework material shall not be less than 20 minutes when tested in accordance with Test Method D3895.

6. Pipe 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. Pipe shall be produced using polyethylene material that complies with Section 5. Pipe shall be produced in accordance with a quality assurance program that complies with Section 9.

6.1.1 Excluding color stripes, the dispersion of carbon black in black pipe and color in solid color pipe shall meet an arithmetic grading mean of 3 or less and an appearance rating not worse than micrograph B when tested in accordance with ISO 18553.

6.1.2 *Carbon Black*—Black pipe shall contain 2.25 ± 0.25 percent carbon black when tested in accordance with Test Method D1603 or Test Method D4218.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameter*—Outside diameter and tolerance shall be as shown in Table 2 or in accordance with 6.2.1.1 when measured in accordance with Test Method D2122.

6.2.1.1 *Special Size Pipe*—Special size pipe is pipe that is not shown in Table 2 that has diameter dimensions that are mutually agreed upon by purchaser and manufacturer, but otherwise complies with this standard. For minimum diameter, d_n, special size pipe, plus tolerance shall be 0.009 times d_n, and minus tolerance shall be zero. For average diameter special size pipe, the plus tolerance shall be 0.0045 times the average diameter, and the minus tolerance shall be 0.0045 times the average diameter. For average diameter special size pipe, minimum diameter, d_n, shall be average diameter less minus tolerance.

NOTE 4—Special size pipe is intended for the manufacture of pipe to dimensions that are by mutual agreement between the purchaser and the manufacturer and not shown in Table 2, but is not intended for the routine manufacture of pipe to inch-based pipe or tubing sizing conventions or "soft metric" conversions of inch-based pipe or tubing.

6.2.2 *Out-of-roundness*—Out of roundness, OOR, shall be measured in accordance with Test Method D2122 at the time of manufacture, but before packaging, storage and shipment. Out of roundness tolerance shall be in accordance with Table 2 or in accordance 6.2.2.1, 6.2.2.2 or 6.2.2.3 for special size pipe. Out of roundness tolerance shall not apply after packaging, storage or shipment.

6.2.2.1 For $d_n \leq 75$ mm, OOR tolerance = 0.008 d_n +1, rounded up to the nearest 0.1 mm

6.2.2.2 For $d_n > 75$ and ≤ 250 mm, OOR tolerance = 0.02 d_n, rounded up to the nearest 0.1 mm

6.2.2.3 For $d_n > 250$ mm, OOR tolerance = 0.035 d_n, rounded up to the nearest 0.1 mm

6.2.3 *Toe-in*—When measured in accordance with Test Method D2122, the outside diameter at the cut end of the pipe shall not be less than 0.985 times the measured undistorted outside diameter. Measurement of the undistorted outside diameter shall be made no closer than 1.5 pipe diameters or 300 mm, whichever distance is less, from the cut end of the pipe. The undistorted outside diameter shall be in accordance with 6.2.1.

6.2.4 *Wall Thickness*—Minimum wall thicknesses and tolerance shall be as shown in Table 2 or 6.2.4.1 when measured in accordance with Test Method D2122. Wall thickness below minimum shall not be acceptable.

6.2.4.1 *Special Size Pipe*—For special size pipe the minimum wall thickness shall be 3.0 mm, but otherwise minimum wall thickness dimensions that are mutually agreed upon between purchaser and manufacturer shall be acceptable. Unless otherwise mutually agreed upon between purchaser and manufacturer, for wall thickness less than 30 mm, wall

TABLE 2 Diameter and Wall Thickness Dimensions and Tolerances, mm

MM Nom. Size	Outside Diameter			Minimum Wall Thickness, t													
				PN 25		PN 20		PN 16		PN 12.5		PN 10		PN 8		PN 6		PN 5	
				DR 7.4		DR 9		DR 11		DR 13.6		DR 17		DR 21		DR 26		DR 33	
	Min. (d_n)	Tol.	OOR Tol.	t	Tol.[A]	t	Tol.[A]	t	Tol.[A]	t	Tol.[A]	t	Tol.[A]	t	Tol.[A]	t	Tol.[A]	t	Tol.[A]
32	32.0	0.3	1.3	4..4	0.6	3.6	0.5	3.0	0.4	...	...	...	...	...	...	...	...	...	...
40	40.0	0.4	1.4	5.5	1.7	4.5	0.6	3.7	0.5	3.0	0.5	...	...	...	...	...	...	...	...
50	50.0	0.4	1.4	6.9	1.8	5.6	0.7	4.6	0.6	3.7	0.5	3.0	0.4	...	...	...	...	...	...
63	63.0	0.4	1.5	8.6	1.0	7.1	0.9	5.8	0.7	4.7	0.5	3.8	0.5	3.0	0.4	...	...	...	...
75	75.0	0.5	1.6	10.3	1.2	8.4	1.0	6.8	0.8	5.6	0.6	4.5	0.6	3.6	0.5	...	...	...	...
90	90.0	0.6	1.8	12.3	1.5	10.1	1.2	8.2	1.0	6.7	0.8	5.4	0.7	4.3	0.6	3.5	0.5	...	...
110	110.0	0.7	2.2	15.1	1.7	12.3	1.4	10.0	1.1	8.1	1.0	6.6	0.8	5.3	0.7	4.2	0.6	...	...
125	125.0	0.8	2.5	17.1	1.9	14.0	1.6	11.4	1.3	9.2	1.1	7.4	0.9	6.0	0.7	4.8	0.6	...	...
140	140.0	0.9	2.8	19.2	2.1	15.7	1.7	12.7	1.4	10.3	1.2	8.3	1.0	6.7	0.8	5.4	0.7	...	...
160	160.0	1.0	3.2	21.9	2.3	17.9	1.9	14.6	1.6	11.8	1.3	9.5	1.1	7.7	0.9	6.2	0.8	...	...
180	180.0	1.1	3.6	24.6	2.6	20.1	2.2	16.4	1.8	13.3	1.5	10.7	1.2	8.6	1.0	6.9	0.8	...	...
200	200.0	1.2	4.0	27.4	2.9	22.4	2.4	18.2	2.0	14.7	1.5	11.9	1.3	9.6	1.1	7.7	0.9	...	...
225	225.0	1.4	4.5	30.8	3.2	25.2	2.7	20.5	2.2	16.6	1.8	13.4	1.5	10.8	1.2	8.6	1.0	...	...
250	250.0	1.5	5.0	34.2	3.6	27.9	4.2	22.7	2.4	18.4	2.0	14.8	1.6	11.9	1.3	9.6	1.1	...	...
280	280.0	1.7	9.8	38.3	4.0	31.3	4.7	25.4	2.7	20.6	2.2	16.6	1.8	13.4	1.5	10.7	1.2	...	...
315	315.0	1.9	11.1	43.1	4.5	35.2	5.3	28.6	3.0	23.2	2.3	18.7	2.0	15.0	1.6	12.1	1.4	9.7	1.1
355	355.0	2.2	12.5	48.5	5.0	39.7	6.0	32.2	4.9	26.1	2.8	21.1	2.3	16.9	1.8	13.6	1.5	10.9	2.2
400	400.0	2.4	14.0	54.7	5.6	44.7	6.8	36.3	5.5	29.4	3.1	23.7	2.5	19.1	2.1	15.3	1.7	12.3	2.4
450	450.0	2.7	15.8	61.5	6.3	50.3	7.6	40.9	6.2	33.1	4.9	26.7	2.8	21.5	2.3	17.2	1.9	13.8	2.7
500	500.0	3.0	17.5	68.4	10.3	55.8	8.4	45.4	6.9	36.8	5.5	29.7	2.9	23.9	2.5	19.1	2.1	15.3	2.7
560	560.0	3.4	19.6	76.6	11.5	62.5	9.4	50.8	7.7	41.2	6.1	33.2	4.9	26.7	2.8	21.4	2.3	17.2	2.9
630	630.0	3.8	22.1	86.1	13.0	70.3	10.6	57.2	8.7	46.3	6.9	37.4	5.6	30.0	4.5	24.1	2.6	19.3	3.1
710	710.0	6.4	24.9	97.1	14.5	79.3	12.0	64.5	9.8	52.2	7.8	42.1	6.3	33.9	5.0	27.2	2.9	21.8	3.3
800	800.0	7.2	28.0	109.3	16.3	89.3	13.5	72.6	11.0	58.8	8.8	47.4	7.1	38.1	5.7	30.6	4.5	24.5	3.6
900	900.0	8.1	31.5	...	...	100.6	15.0	81.7	12.4	66.2	9.9	53.3	7.9	42.9	6.4	34.4	5.1	27.6	3.9
1000	1000.0	9.0	35.0	...	...	111.8	16.7	90.2	13.7	72.5	10.8	59.3	8.8	47.7	7.1	38.2	5.7	30.6	4.5
1200	1200.0	10.8	42.0	...	...	...	...	109.5	16.4	88.2	13.2	67.9	10.1	57.2	8.5	45.9	6.8	36.7	5.5
1400	1400.0	12.6	49.0	...	...	...	...	...	...	102.9	15.4	82.4	12.3	66.7	10.0	53.5	8.0	42.9	6.4
1600	1600.0	14.4	56.0	...	...	...	...	...	...	117.6	17.6	94.1	14.1	76.2	11.4	61.2	9.1	49.0	7.3
1800	1800.0	16.2	63.0	...	...	...	...	...	...	...	...	105.9	15.8	85.7	12.8	69.1	10.3	54.5	8.1
2000	2000.0	18.0	70.0	...	...	...	...	...	...	...	...	117.6	17.6	95.2	14.2	76.9	11.5	60.6	9.0

[A] For minimum wall ≤30.0 mm, tolerance equals 0.1 × minimum wall, rounded up to the nearest 0.1 mm. For minimum wall >30.0 mm, tolerance equals 0.15 × minimum wall, to nearest whole 0.1 mm, with decimal values beyond 0.1 mm dropped.

thickness tolerance shall be 0.10 times minimum wall thickness plus 0.1 mm, and for wall thickness greater than 30 mm, tolerance shall be 0.15 times the minimum wall thickness. (See Note 4.)

6.3 *Short-term Properties*—Specimens of pipe shall be tested for minimum short-term hoop stress and failure mode by hydrostatic bursting, or by apparent ring tensile strength. Hydrostatic bursting is generally applicable to 110 mm and smaller sizes. Apparent ring tensile strength is generally applicable to 63 mm and larger sizes.

6.3.1 *Hydrostatic Bursting*—The minimum hydrostatic burst pressure hoop stress for pipe shall be 20.6 MPa when determined in accordance with 7.4.1. The failure mode shall be ductile.

6.3.2 *Apparent Ring Tensile Strength*—The minimum appar ent ring tensile strength at yield shall be 20.6 MPa when tested in accordance with 7.4.2. The failure mode shall be ductile.

6.4 *Optional Evaluation for Resistance to Rapid Crack Propagation (RCP):*

6.4.1 Evaluation for resistance to rapid crack propagation is optional for pipes intended for the transport of pressurized gas media. Evaluation for RCP is not applicable to pipes intended for the transport of pressurized liquid media, or for non-pressure pipes. Optional RCP evaluation testing is conducted on one sample size in accordance with 7.5.

6.4.2 When one sample size per 7.5 is tested in accordance with ISO 13477 (Small-Scale-Steady-State, S4), the critical pressure in bar at 0°C shall not be less than PN divided by 3.84. When one sample size per 7.5 is tested in accordance with ISO 13478 (Full-Scale, FS), the critical pressure in bar at 0°C shall not be less than PN divided by 1.07.

NOTE 5—If optional evaluation for resistance to rapid crack propagation (RCP) is being contemplated, it is necessary that the purchaser consult with the manufacturer prior to purchase. Information on resistance to RCP may have value for pipes that transport gaseous media under pressure under certain application conditions such as higher pressures at sub-freezing conditions, but is of limited to no value for pipes that transport liquid media under pressure, and is of no value for non-pressure pipes. Review of technical studies on the potential for an RCP event with the fluid media being conveyed is recommended.

6.5 *Elevated Temperature Sustained Pressure*—Elevated temperature sustained pressure tests shall be conducted per 7.6. The test sample shall be three specimens of a generally representative pipe size that is produced in accordance with this specification.

6.5.1 Passing results for all three specimens are non-failure or not more than one ductile failure and an average time before failure that is greater than the Table 3 minimum average time before failure for the selected Table 3 Condition. Any brittle failure constitutes failure to meet this requirement. For testing that is initially performed at Table 3 Condition 1–5, if more than one ductile failure occurs, one retest at a Table 3

TABLE 3 Elevated Temperature Sustained Pressure Requirements

Condition	Test Temperature, °C[A]	Test Pressure Hoop Stress,[B] kPaA	Minimum Average Time Before Failure, Hours[C]
1	80	5170	200
2	80	5020	400
3	80	4870	600
4	80	4715	800
5	80	4565	1000
6	80	4415	1200

[A] Tolerance on test temperature shall be ±2°C. Tolerance on test pressure hoop stress shall be ±35 kPa.
[B] Calculate internal test pressure in accordance with:

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

where:

P = test pressure, kPa,
S = test pressure hoop stress, kPa,
D_O = measured outside diameter, mm, and
t = measured minimum wall thickness, mm.

[C] Table 3 conditions are based on polyethylene 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 at 4260 kPa test pressure hoop stress, the minimum average time before failure would be 926 hours, for example, 200 + ((5170 – 4620) × (1200 – 200) / (5170 –4415)) = 926.

Condition of lower stress and longer minimum average time before failure is permissible, and the retest shall be conducted on three additional specimens of the same size and that were produced within 30 days of the first test specimens. For a retest, any specimen failure, ductile or brittle, at the retest condition constitutes failure to meet this requirement. No retest is permissible for testing that is initially performed at Table 3 Condition 6.

6.6 *Oxidation Induction Time*—The oxidation induction time of the pipe at 200°C shall not be less than 20 minutes when tested in accordance with 7.7.

6.7 *Inside Surface Ductility for Pipe*—The inside surface of pipe shall be ductile as shown by testing in accordance with 7.8. For all specimens, the minimum tensile strength at yield shall be 20.6 MPa and the minimum elongation at break shall be 400 percent.

7. Test Methods

7.1 *Conditioning*—Where conditioning is required before testing, condition pipe test specimens at test temperature without regard to humidity for not less than 24 h in temperature-controlled circulating air equipment that complies with Practice D618, or for not less than 6 hours in temperature-controlled circulating water equipment that complies with Practice D618.

7.2 *Test Conditions*—Conduct laboratory tests in an atmosphere of 23±2°C and 50±10 percent humidity unless otherwise specified in the test methods or this specification. Conduct non-laboratory tests such as routine production floor checks at ambient temperature and humidity conditions.

7.3 *Sampling*—The selection of the polyethylene compound or pipe sample for testing in accordance with this section shall comply with Section 9 Quality Assurance requirements. For referee testing, sample selections shall be by the mutual agreement of the purchaser and the manufacturer. In case of no prior agreement, the testing laboratory shall select samples.

7.4 *Short-term Properties:*

7.4.1 *Hydrostatic Bursting*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599.

7.4.2 *Apparent Ring Tensile Strength*—The procedure and test equipment shall be as specified in Test Method D2290, Procedure D. Test a minimum of five specimens.

7.5 *Resistance to Rapid Crack Propagation (RCP)*—Testing for resistance to rapid crack propagation in accordance with ISO 13477 or ISO 13478 is conducted at 0°C on one sample size having $d_n \leq 350$ mm and having minimum wall thickness ≥ 15 mm.

7.6 *Elevated Temperature Sustained Pressure Test*—Select one Table 3 Condition and test in accordance with Test Method D1598 using water as the internal test medium.

7.7 *Oxidation Induction Time*—A sample specimen taken from the pipe wall shall be tested at 200°C in accordance with Test Method D3895. For referee tests, the sample specimen shall be taken within 0.2 mm of the pipe inner wall.

7.8 *Inside Surface Ductility*—Test specimens from the pipe inside surface for tensile strength at yield and elongation at break in accordance with Test Method D638 at 23±2°C and a crosshead separation speed of 50 mm/min. Prepare five Test Method D638 Type IV specimens cut in the longitudinal direction from each one-fifth circumferential segment around the circumference of the pipe. For all specimens, the pipe ID surface shall be left unaltered. All machined specimen surfaces shall be smooth in accordance with Test Method D638 requirements.