



Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter¹

This standard is issued under the fixed designation D3035; 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.

^{ε1} NOTE—Editorially corrected Table 1. Removed blank footnote ^ε in November 2012.

^{ε2} NOTE—Table 1 alignment was editorially corrected in December 2013.

1. Scope*

1.1 This specification covers polyethylene (PE) pipe made in thermoplastic pipe dimension ratios based on outside diameter and pressure rated for water (see [Appendix X1](#)). Included are requirements for polyethylene compounds and PE plastic pipe, a system of nomenclature for PE plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, and burst pressure. Methods of marking are also given.

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

1.3 The values stated in inch-pound units are to be regarded as 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 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](#)

¹ This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.26 on Olefin Based Pipe.

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² 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.

[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](#)

[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](#)

[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](#)

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

[F412 Terminology Relating to Plastic Piping Systems](#)

2.2 NSF International Standards:

[NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials](#)³

[NSF/ANSI Standard No. 61 for Drinking Water System Components—Health Effects](#)³

2.3 Other Documents:

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

[APWA Uniform Color Code](#)⁵

³ Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

⁴ Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, <http://www.plasticpipe.org>.

⁵ APWA, 2345 Grand Boulevard, Suite 500, Kansas City, MO 64018-2641, <http://www.apwa.net>.

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

TABLE 1 Polyethylene Compound Requirements

Requirement	PE1404	PE2708	Material Designation PE360 Required Value	PE4608	PE4710
HDB at 140°F (60°C), psi (MPa), per ASTM D2837 and PPI TR-3	A	B	B	B	B
HDS for water at 73°F (23°C) psi (MPa), per ASTM D2837 and PPI TR-3 ^C	400 (2.76)	800 (5.5)	800 (5.5)	800 (5.5)	1000 (6.9)
Melt flow rate per ASTM D1238 Specification D3350 Cell Classification Property	1.0 to 0.4 g/10 min Cond. 190/2.16	≤0.40 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6
Density (natural base resin)	1	2	3	4	4
SCG Resistance	4	7	6	6	7
Color and UV Stabilizer Code ^D	C	C, D, or E	C, D, or E	C, D, or E	C, D, or E

^AHDB at 140°F (60°C) not required. Contact manufacturer about pipe use at temperatures other than 73°F (23°C).

^BHDB at 140°F (60°C) required. Contact manufacturer or see PPI TR-4 for listed value.

^CContact manufacturer or see PPI TR-4 for listed value.

^DSee 5.1.1.

[†] Removed extraneous blank footnote.

[‡] Corrected table alignment.

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 *Definitions of Terms Specific to This Standard:*

3.2.1 *relation between dimension ratio, hydrostatic design stress, and pressure rating*—the following expression, commonly known as the ISO equation,⁶ is used in this specification to relate dimension ratio, hydrostatic design stress, and pressure rating:

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

where:

S = hydrostatic design stress for water at 73°F (23°C), psi (MPa),

P = pressure rating, psi (MPa),

*D*₀ = average outside diameter, in. (mm)

t = minimum wall thickness, in. (mm), and,

DR = thermoplastic pipe dimension ratio (*D*₀ / *t* for PE pipe).

4. Pipe Classification

4.1 *General*—This specification covers PE pipe made from PE plastic pipe materials in various dimension ratios and water pressure ratings.

⁶ ISO R 161-1960, Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressure), Part 1, Metric Series.

TABLE 2 Outside Diameters and Tolerances for DR-PR PE Plastic Pipe

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

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

4.3 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall

TABLE 3 Wall Thicknesses and Tolerances^A for DR-PR PE Plastic Pipe

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

^A The minimum is the lowest wall thickness of the pipe allowable at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

be acceptable in engineered products when mutually agreed upon by the customer and manufacturer if (1) the pipe is manufactured from plastic compounds meeting the material requirements of this specification and (2) the strength and design requirements are calculated on the same basis as those used in this specification.

5. Materials

5.1 *Polyethylene Compounds*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall meet thermoplastic materials designation codes PE1404 or PE2708 or PE3608 or PE4608 or PE4710, and shall meet **Table 1** requirements for PE1404 or PE2708 or PE3608 or PE4608 or PE4710, and shall meet thermal stability,

brittleness temperature and elongation at break requirements in accordance with Specification **D3350**

5.1.1 *Color and Ultraviolet (UV) Stabilization*—Per **Table 3**, polyethylene compounds shall meet Specification **D3350** code C, D or E. In addition, Code C polyethylene compounds shall have 2 to 3 percent carbon black, and Code E polyethylene compounds shall have sufficient UV stabilizer to protect pipe from deleterious UV exposure effects during unprotected outdoor shipping and storage for at least eighteen (18) months.

5.1.2 *Colors for solid color, a color shell layer, or color stripes*—In accordance with the APWA Uniform Color Code, blue shall identify potable water service; green shall identify sewer service; purple (lavender) shall identify reclaimed water service. Yellow identifies gas service and shall not be used.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for DR-PR PE Plastic Pipe

Dimension Ratio	Min Burst Pressure, ^A psi (MPa)					
	PE 3608, PE 4608, PE 4710		PE 2708		PE 1404	
	psi	(MPa)	psi	(MPa)	psi	(MPa)
7	967	(6.67)	840	(5.79)	417	(2.87)
9	725	(5.00)	630	(4.34)	313	(2.16)
9.3	699	(4.82)	607	(4.19)	301	(2.08)
11	580	(4.00)	504	(3.47)	250	(1.72)
13.5	464	(3.20)	403	(2.78)	200	(1.38)
15.5	400	(2.76)	348	(2.40)	172	(1.19)
17	363	(2.50)	315	(2.13)	156	(1.08)
21	290	(2.00)	252	(1.74)	125	(0.86)
26	232	(1.60)	202	(1.39)	100	(0.69)
32.5	184	(1.27)	160	(1.10)	79	(0.55)

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

	psi	(MPa)
PE 3608, PE 4608, PE 4710	2900	(20.00)
PE 2708	2520	(17.37)
PE 1404	1250	(8.62)

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

5.3 Rework Material—Clean, rework material from the manufacturer’s own pipe production that met 5.1 through 5.2 as new compound is suitable for use when blended with new compound of the same material designation. Pipe containing the rework material shall meet the requirements of this specification.

6. Requirements

6.1 Workmanship—The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.2 Dimensions and Tolerances:

6.2.1 Outside Diameters—The outside diameters and tolerances shall be as shown in Table 2 when measured in accordance with Test Method D2122. For diameters not shown in Table 2, the tolerances shall be the same percentage of the outside diameter as those for the closest listed diameter.

6.2.2 Wall Thicknesses—The wall thicknesses and tolerances shall be as shown in Table 3 when measured in accordance with Test Method D2122. For wall thicknesses (DRs) not shown in Table 3, the tolerances shall be the same percentage of the calculated minimum wall as for the closest listed minimum wall thickness.

6.2.3 Wall Thickness Range—The wall thickness range shall be within 12 % when measured in accordance with Test Method D2122.

TABLE 5 Apparent Tensile Strength at Yield of Ring Specimens Cut from Pipe

Material	psi	(MPa)
PE 2708	2520	(17.37)
PE 3608, PE 4608, PE 4710	2900	(20.00)
PE 1404	1250	(8.62)

6.3 Short-term Properties—Specimens of pipe shall be tested in accordance with either Test Method D1599 or Test Method D2290. The test method used, Test Method D1599 or Test Method D2290, is determined by the pipe size and the availability of appropriate test equipment. Test Method D1599 is generally used for 4 in. (114 mm) and smaller sizes and Test Method D2290 for 2 in. (60 mm) and larger sizes. Short-term hoop stress and failure mode data is provided by either test.

6.3.1 Burst Pressure—The minimum burst pressure for PE plastic pipe shall be as given in Table 4, when determined in accordance with Test Method D1599 and 7.6. The failure mode shall be ductile.

6.3.2 Apparent Ring Tensile Strength—The minimum apparent ring tensile strength at yield shall be 1250 psi (8.62 MPa) for PE 1404, 2520 psi (17.37 MPa) for Table 1 density cell 2 polyethylene pipe materials, and 2900 psi (20.00 MPa) for Table 1 density cell 3 and 4 polyethylene pipe materials when tested in accordance with Test Method D2290, Procedure B and 7.7. The failure shall be ductile.

6.4 Sustained Pressure at Ambient and Elevated Temperature for PE1404—PE1404 pipes shall be tested in accordance with 7.4 at the stresses and temperatures specified in Table 6. Tests may be conducted on any pipe size, but tests conducted