Designation: F2769 – 23a

An American National Standard

Standard Specification for Polyethylene of Raised Temperature (PE-RT) Plastic Hot and Cold-Water Tubing and Distribution Systems[1]

This standard is issued under the fixed designation F2769; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification establishes requirements for polyethylene of raised temperature (PE-RT) plastic hot- and cold-water tubing and distribution systems components made in one standard dimension ratio and intended for 100 psig (6.9 bar) water service up to and including a maximum working temperature of 180 °F (82 °C). Components are comprised of tubing, fittings, valves and manifolds. Tubing may incorporate an optional polymeric inner, middle or outer layer. Testing of fittings and PE-RT tubing to the requirements of this standard indicate that these fittings are appropriate for use with PE-RT piping systems. Requirements and test methods are included for materials, workmanship, dimensions and tolerances, burst pressure, sustained pressure, oxidative resistance, temperature cycling tests, bend strength and environmental stress cracking. Also included are tests related to system malfunctions. The components covered by this specification are intended for use in residential and commercial, hot and cold, potable water distribution systems, and building supply lines.

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.

NOTE 1—Suggested hydrostatic design stresses and hydrostatic pressure ratings for tubing and fittings are listed in Appendix X1. UV labeling guidelines are provided in Appendix X2. Design, assembly, and installation considerations are provided in Appendix X3. An optional performance qualification and an in-plant quality control program are recommended in Appendix X4.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

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

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

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

D2749 Symbols for Dimensions of Plastic Pipe Fittings

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

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

D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

[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.

[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

F412 Terminology Relating to Plastic Piping Systems
F1055 Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
F1282 Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe
F1290 Practice for Electrofusion Joining Polyolefin Pipe and Fittings
F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
F1960 Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Cross-linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing
F1807 Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring, or Alternate Stainless Steel Clamps, for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing
F2023 Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water
F2159 Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring, or Alternate Stainless Steel Clamps for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
F2735 Specification for Plastic Insert Fittings For SDR9 Cross-linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing
F2080 Specification for Cold-Expansion Fittings with Metal Compression-Sleeves for Crosslinked Polyethylene (PEX) Pipe and SDR9 Polyethylene of Raised Temperature (PE-RT) Pipe

2.2 *ANSI Standard:*[4]
B36.10 Standards Dimensions of Steel Pipe (NTS)
Z 17.1 Preferred Numbers

2.3 *Federal Standard:*[5]
FED-STD-123 Marking for Shipment (Civil Agencies)

2.4 *Military Standard:*[5]
MIL-STD-129 Marking for Shipment and Storage

2.5 *PPI Publications:*[6]
PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe
PPI TR-4 PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

2.6 *NSF Standards:*[7]
NSF 14 Standard No. 14 for Plastic Piping Components and Related Materials
NSF 61 Drinking Water System Components – Health Effects

2.7 *ISO Standard:*[8]
ISO 13760 : Plastics pipes for the conveyance of fluids under pressure -- Miner's rule -- Calculation method for cumulative damage

3. Terminology

3.1 Terminology used in this standard is in accordance with Terminologies F412, D1600, and D2749 unless otherwise specified. The abbreviation for polyethylene of raised temperature is PE-RT. Plastic tubing denotes a particular diameter schedule of plastic pipe in which outside diameter of the tubing is equal to the nominal size plus ⅛ in. Plastic pipe outside diameter schedule conforms to ANSI B36.10.

3.2 *standard dimension ratio (SDR), n*—a specific ratio of the average specified outside diameter to the minimum specified wall thickness (D_0/t) for outside diameter-controlled plastic pipe, the value of which is derived by adding one to the pertinent number selected from the ANSI Preferred Number Series 10. **F412**

3.2.1 *Discussion*—For PE-RT-tubing, it is calculated by dividing the average outside diameter of the tubing in inches or in millimeters by the minimum wall thickness in inches or millimeters. If the wall thickness calculated by this formula is less than 0.070 in. (1.78 mm) it shall be arbitrarily increased to 0.070 in. except for sizes 5⁄16 in. and smaller. The SDR values shall be rounded to the nearest 0.5

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *hydrostatic design stress (HDS), n*—the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the tube will not occur. This stress is circumferential when internal hydrostatic water pressure is applied. For materials with Hydrostatic Strength Classification 3 or 4 per Specification D3350, the HDS is equal to the hydrostatic design basis (HDB) times the design factor (DF) for water. For this standard, the design factor is equal to 0.5.

$$HDS = HDB \times DF$$
$$= HDB \times 0.5 \ (\textit{for this standard})$$

3.3.2 *relation between dimensions, hydrostatic design stress, and pressure rating, n*—the following expression, commonly known as the ISO equation , is used in this specification to relate dimensions, hydrostatic design stress, and pressure rating:

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[5] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/
[6] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.
[7] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, http://www.nsf.org.
[8] 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.

$$2HDS/P = (D_o/t) - 1 \quad (1)$$

or

$$2HDS/P = R - 1$$

where:

HDS = hydrostatic design stress, psi (or MPa),
P = pressure rating, psig (or MPa),
DO = average outside diameter, in. (or mm),
t = minimum wall thickness, in. (or mm), and
R = standard dimension ratio, SDR.

3.3.3 *standard thermoplastic material designated code, n*—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 Specification D3350, the hydrostatic design stress for water at 73 °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.

3.3.3.1 *Discussion*—Further information regarding testing and approval can be obtained from the National Sanitation Foundation or other accredited laboratory.

4. Classification

4.1 *Tubing*—This specification covers one PE-RT tubing material in one standard dimension ratio, 9.0, and by a maximum continuous use temperature that shall be 180 °F (82 °C), and by nominal tubing sizes from ⅛ through 6.

4.2 *Fittings*—This specification classifies fittings, including manifolds, intended for use in systems with PE-RT tubing, by a maximum continuous use temperature that shall be 180 °F (82 °C) and by nominal sizes from ⅛ through 6 on the basis of resistance to burst pressure, hydrostatic sustained pressure, excessive temperature and pressure, and thermocycling.

5. Materials

5.1 *General*—The polyethylene used to make tubing shall be virgin plastic or reworked plastic, or both, as specified in 5.4, that meets the requirements of this standard and shall have a Plastic Pipe Institute (PPI) rating at 73 °F (23 °C) and 180 °F (82 °C). Fitting materials shall meet the applicable material requirements of a least one of the Specifications D2683, D3261, F1055, F1807, F1960, F2080, F2159, or F2735. Polyethylene material used in fusion fittings shall meet the requirements of Table 1 and Table 2. Fittings shall be made from materials that are generally regarded as corrosion resistant.

5.2 *Basic Tubing Materials*—PE-RT tubing meeting the requirements of this specification are primarily defined by two criteria namely, basic short-term properties, 5.2.1, and long-term hydrostatic properties, 5.2.2.

5.2.1 *Basic Short-Term Properties*—This specification covers tubing materials meeting the following requirements:

5.2.1.1 *Classification*—Polyethylene materials suitable for use in the manufacture of tubing under this specification shall be classified in accordance with Specification D3350 as shown in Table 1.

5.2.2 *Long-Term Hydrostatic Strength*—This specification covers PE-RT tubing which is further defined on the basis of long-term hydrostatic strength tests (Appendix X1). The material shall have a minimum pressure rating as per Table 2.

5.3 *Barrier Layers*—PE-RT tubing may incorporate an optional interior wall, mid wall or outer wall layer or a combination of such layers of non-PE-RT material for the express purpose of providing gas barrier properties to the pipe. The tubing shall meet the minimum wall thickness requirements of this standard without using the barrier layer thickness in the determinations. PE-RT tubing with a barrier layer within the wall of the tubing (neither exterior layer nor interior layer) shall demonstrate a hydrostatic design stress (HDS) rating equivalent to that of PE-RT tubing without a barrier layer. This determination shall be made in accordance with policies no less restrictive than those of the PPI TR-3 and meet the requirements of this standard.

5.4 *Rework Material*—Clean rework material of the same commercial designation, generated from the manufacturer's own tubing production shall not be used unless the tubing produced meet all the requirements of this specification. PE-RT tubing with a barrier layer shall not be used for rework material.

5.5 *Tubing Material Designation*—The tubing meeting the requirements of this specification shall be designated PE-RT.

5.6 *Certification*—Tubing and fittings intended for use in the transport of potable water shall be evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation shall be in accordance with the requirements for chemical extraction that are not less restrictive than those included in NSF Standard 61. The seal or mark of the laboratory making the evaluation shall be included on the tubing.

NOTE 2—Further information regarding testing and approval can be obtained from an accredited certification provider.

6. Requirements

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

TABLE 1 Required D3350 Cell Classification for PE-RT

Physical Properties:	Cell Classification
Density	3 or 4
Melt index	2, 3, 4, or 5
Flexural modulus	3 or higher
Tensile strength	2 or higher
Slow crack growth resistance	7
Hydrostatic Strength Classification	3 or 4

TABLE 2 Pressure Ratings for PE-RT SDR 9 Tubing for Water

Rated Temperature		Minimum Hydrostatic Design Stress		Minimum Pressure Rating for Water	
°F	(°C)	psi	(MPa)	psi	(bar)
73.4	(23)	640	(4.41)	160	(11.0)
180	(82.2)	400	(2.76)	100	(6.90)

properties. For tubing that incorporates a barrier layer per 5.3 each layer shall meet the workmanship requirements per this section.

6.2 *Dimensions and Tolerances:*

6.2.1 The dimensions and tolerances of fittings shall meet the specific requirements contained in Specifications D2683, D3261, F1055, F1807, F1960, F2080, F2159, F2735, or other recognized specification.

6.2.2 *Outside Diameters of Tubing*—The outside diameters and tolerances of the tubing including the layers shall be as shown in Table 3, when measured in accordance with 7.4 and 7.4.1.

6.2.3 *Wall Thickness of Tubing*—The wall thickness and tolerances shall be as shown in Table 4, when measured in accordance with 7.4 and 7.4.2.

6.2.3.1 *Layer*—Tubing that incorporates an inner, middle or outer layer shall meet the minimum wall thickness and tolerances requirements as specified in Table 4. In addition, the layer shall not result in the reduction of the total PE-RT material below that specified in Table 4. In the case of tubing with a middle layer, the total base PE-RT material wall thickness shall be the sum of the inner and outer base PE-RT material wall thicknesses.

6.2.4 *Out-of-Roundness*—The maximum out-of-roundness requirements shown in Table 3 for tubing, apply to the average measured diameter. Tubing shall be measured prior to coiling.

6.3 *Sustained Pressure*—The tubing and fittings, assembled using the manufacturer's instructions and tested as assemblies, shall not fail, balloon, burst, or weep at the test pressures given in Table 5 when tested in accordance with 7.5.

6.3.1 If present, valves shall be tested in the open or unrestricted position.

6.4 *Burst Pressure*—The tubing and fittings, assembled using the manufacturer's instructions and tested as assemblies, shall meet the minimum burst pressure given in Table 6, when determined in accordance with 7.6. Leakage or separation at any of the fittings tested shall constitute failure of the fitting.

6.4.1 If the manifold has more than one connection size, the test pressure selected from Table 5 shall be based on the largest nominal tubing connection.

6.5 *Oxidative Resistance in Potable Chlorinated Water Applications*—PE-RT tubing chlorine classification codes shall be determined based on a minimum extrapolated time-to-failure of 50 years when tested and evaluated in accordance with 7.8 and Table 7.

6.6 *Bent Tube*—The following requirement applies to tubing up to 1 in. nominal diameter. Bent tubing, with a radius of 6 times the outside diameter and consisting of a continuous bend length inducing not less than 90° angle, shall meet the 180 °F (82.2 °C) minimum hydrostatic sustained pressure strength requirements shown in Table 5 when tested in accordance with 7.9. The bend length and bend angle is kept throughout the testing period by rigid secures immediately outside the bend. The minimum test duration shall be 1000 h without failure.

NOTE 3—PE-RT tubing, larger than 1 in. nominal diameter, is typically installed as main distribution lines and is installed in straight runs. Fittings are used when a change in direction of 90° or greater and a bend radius of less than 6 times the outside diameter is needed. The test requirements in 6.7 are intended to evaluate PE-RT tubing installed in tight bend applications in accordance with the procedure in Appendix X3. This application applies to tubing up to and including 1 in. nominal diameter only.

6.7 *Excessive Temperature Hydrostatic Sustained*— Tubing and fittings, when tested as assemblies, shall not fail in less than 720 h when tested in accordance with 7.10. If present, valves shall be tested in the open or unrestricted position.

NOTE 4—Tests applicable to tubing and fitting assemblies (6.3, 6.4, 6.7, and 6.12.3) are intended to be performance qualification tests of joints and not tests required of each fitting configuration.

6.8 *Environmental Stress Cracking*—There shall be no loss of pressure in the tubing, when tested in accordance with 7.11.

6.9 *Adhesion Test*—Tubing that incorporates an optional inner, middle or outer layer shall not show any delamination when tested in accordance with 9.3.1 of Specification F1282.

TABLE 3 Outside Diameters and Tolerances for PE-RT Tubing

Nominal Tubing Size		Average Outside Diameter		Tolerances for Average Diameter		Out-of-Roundness[A]	
in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
⅛	(3)	0.250	(6.35)	±0.003	(±0.08)	0.008	(0.20)
¼	(7)	0.375	(9.52)	±0.003	(±0.08)	0.008	(0.20)
5⁄16	(8)	0.430	(10.92)	±0.003	(±0.08)	0.008	(0.20)
⅜	(10)	0.500	(12.70)	±0.003	(±0.08)	0.012	(0.32)
½	(13)	0.625	(15.88)	±0.004	(±0.10)	0.016	(0.40)
⅝	(16)	0.750	(19.05)	±0.004	(±0.10)	0.016	(0.40)
¾	(19)	0.875	(22.22)	±0.004	(±0.10)	0.016	(0.40)
1	(25)	1.125	(28.58)	±0.005	(±0.12)	0.020	(0.48)
1¼	(32)	1.375	(34.92)	±0.005	(±0.12)	0.020	(0.48)
1½	(38)	1.625	(41.28)	±0.006	(±0.16)	0.024	(0.60)
2	(51)	2.125	(53.98)	±0.006	(±0.16)	0.030	(0.76)
2½	(64)	2.625	(66.68)	±0.007	(±0.18)	0.038	(0.95)
3	(76)	3.125	(79.38)	±0.008	(±0.20)	0.045	(1.14)
3½	(89)	3.625	(92.08)	±0.008	(±0.20)	0.046	(1.16)
4	(102)	4.125	(104.78)	±0.009	(±0.23)	0.052	(1.32)
4½	(114)	4.625	(117.48)	±0.009	(±0.23)	0.059	(1.49)
5	(127)	5.125	(130.18)	±0.010	(±0.25)	0.065	(1.65)
6	(152)	6.125	(155.58)	±0.011	(±0.28)	0.072	(1.83)

[A] The Out-of-Roundness specification applies only to tubing prior to coiling.

TABLE 4 Wall Thickness and Tolerances for PE-RT SDR 9 Tubing[A]

Nominal Tubing		Minimum Wall Thickness		Tolerance	
in.	(mm)	in.	(mm)	in.	(mm)
⅛	(3)	0.047[B]	(1.19)[B]	+0.007	(+0.18)
¼	(7)	0.062[B]	(1.57)[B]	+0.010	(+0.25)
5/16	(8)	0.064	(1.63)	+0.010	(+0.25)
⅜	(10)	0.070[B]	(1.78)[B]	+0.010	(+0.25)
½	(13)	0.070[B]	(1.78)[B]	+0.010	(+0.25)
⅝	(16)	0.083	(2.12)	+0.010	(+0.25)
¾	(19	0.097	(2.47)	+0.010	(+0.25)
1	(25)	0.125	(3.18)	+0.013	(+0.33)
1¼	(32)	0.153	(3.88)	+0.015	(+0.38)
1½	(38)	0.181	(4.59)	+0.019	(+0.48)
2	(51)	0.236	(6.00)	+0.024	(+0.61)
2½	(64)	0.292	(7.41)	+0.030	(+0.76)
3	(76)	0.347	(8.82)	+0.033	(+0.84)
3½	(89)	0.403	(10.23)	+0.035	(+0.89)
4	(102)	0.458	(11.64)	+0.040	(+1.02)
4½	(114)	0.514	(13.05)	+0.045	(+1.14)
5	(127)	0.569	(14.46)	+0.050	(+1.27)
6	(152)	0.681	(17.29)	+0.060	(+1.52)

[A] The minimum is the lowest wall thickness of the tubing 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.
[B] For tubing sizes of ½ in. and below, wall thickness minimums are not functions of SDR.

TABLE 5 Sustained Water Pressure Test Condition for PE-RT SDR 9 Tubing

Nominal Tubing Size	Pressure Required for Test, psig A[A] (MPa)							
	For 1250 psi HDB at 73.4 °F				For 1600 psi HDB at 73.4 °F			
	73 °F	(23 °C)	180 °F	(82 °C)	73 °F	(23 °C)	180 °F	(82 °C)
⅛	595	(4.10)	355	(2.45)	740	(5.10)	355	(2.45)
¼	515	(3.55)	305	(2.10)	635	(4.38)	305	(2.10)
5/16	455	(3.14)	270	(1.86)	560	(3.86)	270	(1.86)
⅜	425	(2.93)	250	(1.72)	520	(3.59)	250	(1.72)
½	330	(2.28)	195	(1.34)	405	(2.79)	195	(1.34)
⅝ and larger	325	(2.24)	190	(1.31)	400	(2.76)	190	(1.31)

[A] The fiber stresses used to derive these test pressures are:
at 73 °F (23 °C) 1300 psi (8.96 MPa) for a 1250 psi HDB material and 1600 psi (11.0 MPa) for a 1600 psi HDB material
at 180 °F (82 °C) 770 psi (5.31 MPa)

TABLE 6 Burst Water Pressure Test Condition for PE-RT SDR 9 Tubing

Nominal Tubing Size	Pressure Required for Test, psig[A] (MPa)							
	For 1250 psi HDB at 73 °F				For 1600 psi HDB at 73 °F			
	73 °F	(23 °C)	180 °F	(82 °C)	73 °F	(23 °C)	180 °F	(82 °C)
⅛	870	(6.00)	495	(3.41)	1345	(9.28)	495	(3.41)
¼	752	(5.19)	420	(2.90)	1150	(7.93)	420	(2.90)
5/16	660	(4.55)	370	(2.55)	1015	(7.00)	370	(2.55)
⅜	620	(4.27)	345	(2.38)	945	(6.52)	345	(2.38)
½	480	(3.31)	270	(1.86)	730	(5.03)	270	(1.86)
⅝ and larger	475	(3.27)	265	(1.83)	720	(4.97)	265	(1.83)

[A] The fiber stresses used to derive these test pressures are:
at 73 °F (23 °C) 1900 psi (13.10 MPa) for a 1250 psi HDB material and 2900 psi (20.0 MPa) for a 1600 psi HDB material
at 180 °F (82 °C) 1065 psi (7.33 MPa)

TABLE 7 Oxidative Resistance Classification Codes

Standard	CL1	CL2	CL3	CL4	CL5
Usage Ratios	75% at 73 °F and 25 % at 140 °F	Reserved for future use	50% at 73 °F and 50 % at 140 °F	Reserved for future use	100% at 140 °F

6.10 *Slow Crack Growth Resistance*—The slow crack growth resistance of the tubing material shall not be less than 500 h when tested in accordance with 7.12.

6.11 *Joints-Fusion:*

6.11.1 Tubing may be fusion joined using Specification F1055 electrofusion fittings, Specification D2683 socket fusion fittings or Specification D3261 butt heat fusion fittings. The tubing manufacturer shall indicate the recommended fitting types for use with their tubing as indicated in Section 9.

6.11.2 Tubing with external barrier layers shall only be joined by fusion if recommended by the tubing manufacturer and tubing is prepared so as to completely remove the barrier layer within the fusion zone per the tubing manufacturer's recommendations. Tubing with mid-wall barrier layers shall not be joined with fusion fittings.

NOTE 5—An external barrier layer will compromise electrofusion or

socket fusion joining if not completely removed. A mid-wall barrier layer will compromise butt fusion joining. Exposure of the a mid-wall barrier layer to the transported fluid may degrade the layer performance.

6.11.3 *Electrofusion:*

6.11.3.1 Electrofusion joints between tubing and Specification F1055 fittings shall be made in accordance with Practice F1290 and the fitting manufacturer's instructions.

6.11.3.2 Qualification of the fitting with PE-RT tubing shall be performed in accordance with 6.3, 6.4 and Specification F1055.

6.11.4 *Socket Fusion:*

6.11.4.1 Socket fusion joints between tubing and Specification D2683 fittings shall be made in accordance with Practice F2620 and the fitting manufacturer's instructions.

6.11.4.2 Qualification of Specification D2683 fittings with PE-RT shall be performed in accordance with 6.3, 6.4.

6.11.5 *Butt Heat Fusion:*

6.11.5.1 Butt fusion joints between tubing and Specification D3261 fittings shall be made in accordance with Practice F2620 and the fitting manufacturer's instructions.

6.11.5.2 Qualification of the fitting with PE-RT shall be performed in accordance with 6.3, 6.4.

6.12 *Joints - Mechanical Insert:*

6.12.1 Mechanical insert fittings shall be installed in accordance with the fitting manufacturer's installation instructions.

6.12.2 Qualification of the fitting with PE-RT tubing in accordance with 6.3, 6.4, and 6.12.3.

6.12.3 *Thermo-cycling*—Tubing and mechanical insert joint system components, assembled using the system component manufacturer's instructions, shall not leak after completion of 1000 cycles between the temperatures of 60 °F (16 °C) and 180 °F (82 °C) when tested in accordance with 7.7.

7. Test Methods

7.1 *Conditioning*—Condition the specimens at 73.4 °F ± 3.6 °F (23 °C ± 2 °C) and 50 % ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ± 1.8 °F (±1 °C) and ± 2 % relative humidity.

7.2 *Test Conditions*—Conduct the test in the standard laboratory atmosphere of 73.4 °F ± 3.6 °F (23 °C ± 2 °C) and 50 % ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be ±1.8 °F (±1 °C) and ±2 % relative humidity.

7.3 *Sampling*—A sufficient quantity of tubing or fittings, as agreed upon by the purchaser and the seller, shall be selected and tested to determine conformance with this specification (see Practice D1898). In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

7.3.1 *Test Specimens*—Unless otherwise specified in this standard or as agreed upon by the purchaser and the seller, the quantity and size of the specimens to be tested shall be as specified by the test method referred to in this standard. If present, valves shall be tested in the open or unrestricted position.

7.4 *Dimensions and Tolerances*—Use any length of tubing to determine the dimensions. Measure in accordance with Test Method D2122.

7.4.1 *Outside Diameter*—Measure the outside diameter of the tubing in accordance with Test Method D2122. The referee method of measurement is to be by circumferential wrap tape. The tolerance for out-of-roundness shall apply only to tubing prior to shipment. Averaging micrometer or vernier caliper measurements, four (4) maximum and minimum diameter measurements at any cross section, may be used for quality control checks if desired.

7.4.2 *Wall Thickness*—Make micrometer measurements of the wall thickness in accordance with Test Method D2122 to determine the maximum and minimum values. Measure the wall thickness at both ends of the tubing to the nearest 0.001 in. (0.025 mm).

7.4.2.1 *Layer*—Make measurements of the layer or layers using either a video microscope, a microscope with 0.001 inch graduation or optical comparator to determine the maximum and minimum values.

7.5 *Sustained Pressure Test*—Select the test specimens at random. Test at least six joints and at least six tubing specimens as per Test Method D1598 in water at 73 °F (23 °C) and 180 °F (82.2 °C) as shown in Table 5. Each specimen of tubing shall be at least five times the nominal diameter in length and not less than 12 in. (25 cm) or more than 3.0 ft (91 cm) between end closures. Maintain the specimens at the pressures indicated for the appropriate temperatures for a period of 1000 h. Failure of two of the six specimens tested at either temperature constitutes failure in the test. Failure of one of six tubing or fitting specimens tested at either temperature is cause for retest of six additional tubing or fitting specimens, respectively, at that temperature. Failure of one of six tubing or fitting specimens tested at either temperature in retest constitutes failure of the tubing or fitting, respectively, in the test. Failure of the tubing or fitting shall be defined in accordance with Test Method D1598 and leakage or separation at any of the fittings tested shall constitute failure of the fitting. Delamination of the tubing shall constitute failure of the tubing.

7.6 *Burst Pressure*—Determine the tubing or fitting complies with the minimum burst pressure requirements by testing in accordance with Test Method D1599 Method B. Test at least six joints and at least six tubing specimens as per Test Method D1599 in water at 73 °F (23 °C) and 180 °F (82.2 °C) as shown in Table 6. Each specimen of tubing shall be at least five times the nominal diameter in length and not less than 12 in. (25 cm) or more than 3.0 ft (91 cm) between joints. Leakage or separation at any of the fittings tested shall constitute failure of the fitting.

7.6.1 If present, valves shall be tested in the open or unrestricted position.

7.7 *Thermocycling:*

7.7.1 *Summary of Test Method*—This test method describes a pass-fail test for thermally cycling PE-RT tubing and fittings assemblies over a critical temperature range for a selected number of cycles while subjected to a nominal internal pressure. This test method provides a measure of resistance to

failure due to the combined effects of differential thermal expansion and creep for PE-RT tubing and fittings intended for continuous use up to and including 180 °F (82 °C).

7.7.2 *Apparatus*—A nitrogen or air source capable of maintaining a nominal internal pressure of 100 psig ± 10 psig (6.9 bars ± 0.69 bars) within the specimens is required. The immersion system shall consist of two water reservoirs controlled at 60 °F ± 4 °F (16 °C± 2 °C) and 180 °F ± 4 °F (82 °C ± 2 °C). The specimen shall be cycled from one reservoir to the other or the hot and cold water shall be alternately cycled over the test specimens automatically and returned to the proper reservoirs.

NOTE 6—Automatic cycling may be accomplished by pumping from each reservoir, through a delivery system having timer-actuated valves, to a specimen water trough having synchronized, timer-actuated return drains. Any automatic apparatus shall provide for complete immersion of the test specimen in the trough.

7.7.3 *Sampling and Specimen Preparation*—Select at least six joints from randomly selected specimens assembled per the manufacturer's instructions. Close the specimen assembly with any suitable end closures that allow "free-end" mounting and will not leak under the thermocycling conditions, and connect the specimen assembly to the pressure source.

7.7.3.1 If present, valves shall be tested in the open or unrestricted position.

7.7.4 *Procedure*—Pressurize the specimen assembly with nitrogen or air to 100 ± 10 psig (0.69 ± 0.069 MPa). Immerse in 60 ± 4 °F (16 ± 2 °C) water to determine if there are any initial leaks. All leaks shall be eliminated before the thermocycling test is started. Thermally cycle the specimen assembly either manually or automatically and under an internal pressure of 100 psig ± 10 psig (0.69 MPa ± 0.069 MPa), alternately between 60 °F ± 4 °F (16°C ± 2 °C) and 180 °F ± 4 °F (82 °C ± 2 °C) by means of immersion in water using the following test cycle: Water immersion at 180 °F (82 °C) 2 min (min) Air immersion at ambient 2 min (max) Water immersion at 60 °F (16 °C) 2 min (min) Air immersion at ambient 2 min (max) Upon the completion of 1000 thermal cycles, immerse the specimen assembly again in 60 °F ± 4 °F (16 °C ± 2 °C) water and check for any sign of gas leakage. Any evidence of leakage at the fitting or separation of the fitting from the tubing constitutes a failure.

7.7.5 *Interpretation of Results*—Failure of any one of six joints tested shall constitute failure of this test.

7.8 *Oxidative Stability in Potable Chlorinated Water:*

7.8.1 The test shall be conducted and the extrapolated time-to-failure shall be determined in accordance with Test Method F2023. The test fluid shall be prepared in accordance with 9.1.1 of Test Method F2023. The extrapolated time-to-failure shall be calculated using the coefficients from 13.1 of Test Method F2023, and using Miners Rule, calculate the estimated time to-failure for a hoop stress corresponding to a sustained internal pressure of 80 psig (551.7 kPa) for the DR of the tested specimens at the temperature exposure conditions and usage ratios defined in Table 7 in accordance with ISO 13760.

7.8.2 *Significance*—The test need only be performed on representative pipe samples for the original validation of pipe made from a particular compound. A compound is defined as the PE-RT resin and the stabilization system.

7.9 *Bent Tube Test*—Conduct the sustained pressure test on a bent tube sample in accordance with Test Method D1598, except that the test temperature shall be 180 °F (82 °C).

7.10 *Excessive Temperature and Pressure Capability of Tubing and Fittings:*

7.10.1 Determine in accordance with Test Method D1598, except for the following requirements:

7.10.1.1 Test at least six joints from randomly selected specimens assembled per the manufacturer's instructions with at least 5-pipe diameters between joints.

7.10.1.2 Condition tubing and fittings as assemblies in accordance with 7.1.

7.10.1.3 Test temperature shall be 210 °F ± 4 °F (99 °C ± 2 °C).

7.10.1.4 The external test environment shall be air.

7.10.1.5 Fill the specimens with water and condition for 2 h at a temperature of 210 °F ± 4 °F (99 °C ± 2 °C) and a pressure of 30 psi ± 3 psi (207 kPa ± 21 kPa)

7.10.1.6 .Pressurize test specimens to the required pressure and maintain for 720 h. The pressure for PE-RT SDR 9 tubing shall be 150 psi (10.34 bar).

7.11 *Environmental Stress Cracking Test*—Test six randomly selected 10 in. to 15 in. (250 mm to 375 mm) long specimens for this test.

NOTE 7—Straight or previously coiled specimens are permissible although straight specimens are preferred for ease of notching and accurate control of the notch depth.

7.11.1 Within each specimen make a notch on the inside of the tubing wall in the axial direction. The notch depth shall be 10.3 % of minimum wall thickness as specified in Table 3 for the specimen tubing size. The notch depth tolerance shall be ±0.0005 in. (± 0.013 mm) and the full depth notch shall be 1.0 in. ± 0.1 in. in length (25 mm ± 3 mm). Use a sharp blade mounted in a jig to make this notch. Use a depth micrometer or other means for setting the blade in the jig so that the notch depth is controlled as specified. The notch shall be placed, at its nearest point, at least 1.5 times the nominal diameter away from end closures.

7.11.2 Fill the tubing with the test medium which is 5.0 % ± 0.5 % by weight nonylphenoxy poly(ethyleneoxy) ethanol mixed with 95 % of untreated water.

NOTE 8—The nonylphenoxy poly(ethyleneoxy) ethanol has historically been synonymous with "Igepal CO-630," for example, CAS# 68412-54-4 or CAS# 9016-45-9. This test has been historically performed with untreated water, generally meaning potable tap water supplied by utilities. Environmental stress cracking is a failure mode normally apparent after long-term use of tubing. The use of a surfactant and 180 °F (93 °C) test conditions are intended to produce results indicative of expected longterm performance in a reasonable time frame. Nonylphenoxy poly(ethyleneoxy) ethanol waste is considered in some jurisdictions to be environmentally hazardous. For disposal of nonylphenoxy poly(ethyleneoxy) ethanol waste local regulations should be consulted and adhered to.

7.11.3 Test the specimens in accordance with Test Method D1598 for 100 hours at 180 °F (82 °C) using the pressure specified in Table 5 for 180 °F (82 °C) and the tubing size. Testing shall be conducted in accordance with Test Method