Designation: F2929 – 17

An American National Standard

Standard Specification for Crosslinked Polyethylene (PEX) Tubing of 0.070 in. Wall and Fittings for Radiant Heating Systems up to 75 psig[1]

This standard is issued under the fixed designation F2929; 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 0.070 in. wall thickness crosslinked polyethylene (PEX) tubing that is outside diameter controlled, and intended for non-potable radiant heating applications for pressures up to 75 psig in sizes ⅝ NTS (nominal tubing size) and ⅞ NTS. This specification also includes fittings that are specifically designed for this 0.070 in.-wall PEX tubing. Only maximum 75-psig relief valves shall be used with this tubing. Included in this specification are requirements and test methods for material, workmanship, dimensions, burst pressure, hydrostatic sustained pressure, environmental stress cracking, stabilizer functionality, bent-tube hydrostatic pressure, excessive temperature and degree of crosslinking. Requirements for tubing markings are also given. This specification incorporates an optional middle or outer oxygen barrier layer. This tubing is not intended for field bending at temperatures above 120 °F (49 °C).

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 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:*

A269/A269M Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A276/A276M Specification for Stainless Steel Bars and Shapes

A312/A312M Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

B16/B16M Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines

B61 Specification for Steam or Valve Bronze Castings

B62 Specification for Composition Bronze or Ounce Metal Castings

B140/B140M Specification for Copper-Zinc-Lead (Red Brass or Hardware Bronze) Rod, Bar, and Shapes

B283 Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)

B371/B371M Specification for Copper-Zinc-Silicon Alloy Rod

B584 Specification for Copper Alloy Sand Castings for General Applications

B967/B967M Specification for Copper-Zinc-Tin-Bismuth Alloy Rod, Bar and Wire

D618 Practice for Conditioning Plastics for Testing

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2765 Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics

D2837 Test Method for Obtaining Hydrostatic Design Basis

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water.

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

for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
E18 Test Methods for Rockwell Hardness of Metallic Materials
F412 Terminology Relating to Plastic Piping Systems
F1281 Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe
F2657 Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing

2.2 *ANSI Standard:*[2]
B36.10 Standards Dimensions of Steel Pipe (IPS)

2.3 *Federal Standard:*[3]
FED-STD-123 Marking for Shipment (Civil Agencies)

2.4 *Military Standard:*[3]
MIL-STD-129 Marking for Shipment and Storage

2.5 *ISO Standards:*[4]
ISO 1167 Thermoplastics pipes, fittings and assemblies for the conveyance of fluids -- Determination of the resistance to internal pressure -- Part 1: General method
ISO R 161-1690 Pipes of Plastic Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part 1, Metric Series
ISO 17455 Plastics piping systems -- Multilayer pipes -- Determination of the oxygen permeability of the barrier pipe

2.6 *PPI Standards:*[5]
PPI TR-3 Policies and Procedures for Developing Recommended Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) 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

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for crosslinked polyethylene is PEX.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *barrier layer, n*—a very thin polymeric film within the tube wall or around the circumference of the tubing, which provides a means for greatly reducing the transmission of oxygen from the atmosphere and into the fluid within the tube.

3.2.2 *crosslinked polyethylene, n*—molecular polyethylene chains chemically connected through irradiation with high-energy electron beams, or chemical agents such as organic peroxides or silanes.

3.2.3 *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. 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 0.50.

$$HDS = HDB \times DF$$
$$= HDB \times 0.05 \quad \text{(For this standard)} \qquad (1)$$

3.2.4 *hydrostatic design basis (HDB)*—one of a series of established stress values (specified in Test Method D2837) for a plastic compound obtained by categorizing the long-term hydrostatic strength determined in accordance with Test Method D2837.

3.2.4.1 *Discussion*—A listing of HDB and HDS values are contained in PPI publication PPI TR-4.

3.2.5 *hydrostatic strength equivalency (HSE), n*—a pressure testing evaluation methodology where hydrostatic testing is conducted on PEX tubing that is constructed with a barrier layer in the middle or outside wall of the tubing, and is constructed with PEX material that has an established HDB. HSE methodology is applied where the barrier layer reduces the thickness of the HDB rated PEX material in the wall such that the PEX wall thickness excluding the barrier layer(s) is slightly less than 0.070 in. (1.78 mm).

3.2.6 *HSE-DR, n*—an identifying term for the tubing where the minimum PEX wall thickness falls below 0.070 in. (1.78 mm), yet the tubing, as constructed, still meets the pressure rating requirements of this specification as demonstrated by HSE evaluation testing.

3.2.7 *pressure rating (PR)*—the estimated maximum water pressure the tube is capable of withstanding continuously with a high degree of certainty that failure of the tube will not occur.

3.2.7.1 *Discussion*—If both ⅝ NTS and ⅞ NTS tubing are used in the same system, the pressure rating of the system is limited to the pressure rating of the ⅞ NTS tubing.

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

$$2S/P = (D_O / t) - 1$$
or
$$2S/P = R - 1 \qquad (2)$$

where:

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

[2] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[3] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.
[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.
[5] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.

3.2.9 *tubing material designation code*—The tubing material designation code shall consist of the abbreviation for the type of plastic (PEX) followed by four Arabic digits that describe short-term properties in accordance with applicable ASTM standards and as shown in Table 1.

3.2.9.1 *Discussion*—The first digit is for chlorine resistance, which is not applicable for radiant tubing applications, but is mentioned here for information purposes.

3.2.9.2 *Discussion*—The second digit is for demonstrated UV resistance of PEX material when tested in accordance with Test Method F2657. For radiant heating, it shall be one of the classification digits from Table 1 for the nominal exposure time period from Table 1 of Test Method F2657 where the UV-exposed samples meet the requirement of 7.10 Stabilizer Functionality. The UV resistance shall be demonstrated on representative pipe samples for the original validation of pipe made from a particular PEX material, that material being the combination of PEX resin and its additive system.

3.2.9.3 *Discussion*—The last two digits are 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. Thus, a complete material designation code for PEX tubing shall consist of the three letters "PEX" and four digits.

3.2.10 *0.070 in. wall radiant heating system*—PEX tubing with a 0.070 in. thickness, and corresponding fittings designed for 0.070 in. wall tubing, used for radiant heating applications.

4. Tubing Classification

4.1 *General*—This specification covers tubing for 0.070 in. wall radiant heating that is classified using the tubing material designation code for PEX tubing.

5. Materials

5.1 *Tubing*—Crosslinked polyethylene tubing, meeting the requirements of this specification, is primarily defined by means of three criteria, namely, *(1)* nominal density, *(2)* degree of crosslinking, and *(3)* long-term strength tests. There is a strong correlation between nominal density and results of short-term strength tests.

5.1.1 *Basic Materials*—PEX tubing, exclusive of optional barrier layer, shall be made from polyethylene compounds, which have been crosslinked by peroxides, Azo compounds, or silane compounds in extrusion, or by electron beam after extrusion, or by other means such that the tubing meets the performance requirements of Section 6. For the use temperatures that the tubing will be marked for, the materials, procedure for mixing, and the process for crosslinking shall result in a product with long-term hydrostatic design basis (HDB) ratings equal to or better than 1250 psi at 73 ºF (23 ºC), 1000 psi at 120 ºF (49 ºC), and 800 psi at 180 ºF (82 ºC), when determined in accordance with procedures no less restrictive than those of PPI TR-3. See Appendix X1 for additional information on PPI hydrostatic stress ratings.

NOTE 1—HDB values at 73 ºF (23 ºC) and 180 ºF (82 ºC) may be published in PPI TR-4. The HDB at an intermediate temperature, such as 120 ºF (49 ºC), is determined by arithmetic interpolation.

NOTE 2—Tubing produced by crosslinking by peroxides, Azo compounds, or silane compounds in extrusion, or by electron beam after extrusion have met the requirements of Section 6. There are several other processes for producing crosslinked polyethylene tubing. However, each process must be established as meeting the requirements of this specification.

5.1.2 *Barrier Layer*—A barrier layer to reduce oxygen diffusion is optional for this tubing. Tubing incorporating an optional layer shall meet the requirements of 6.14 and 6.15 and all other requirements of this specification.

5.1.2.1 Polymeric oxygen barrier layer materials shall be compatible with PEX and meet the requirements of this specification.

NOTE 3—EVOH (Ethylene vinyl alcohol), which is the typical material used for the barrier layer, is defined by the mole % ethylene content: lower ethylene content grades have higher oxygen barrier properties.

5.1.2.2 Bonding or tie layer(s) material (if present) shall be compatible with both PEX and barrier layer providing for permanent bonding between layers to meet layer adhesion requirements of 6.14. A bonding/tie layer containing a colorant shall be acceptable.

5.1.2.3 All barrier tubing sizes in this specification are pressure rated equivalent to DR of the PEX tubing. Tubing that has PEX material minimum wall thickness equal to or greater than 0.070 in. (1.78 mm) is pressure rated as that DR using the design equation (3.2.8), and is marked with that DR. Tubing having a barrier layer that has PEX material minimum wall thickness that is less than 0.070 in. (1.78 mm) is pressure rated using hydrostatic strength equivalency (HSE) testing (6.3.2.3), and is marked "HSE-DR."

5.2 *Fittings*—The fittings shall be made from one of the following metals:

5.2.1 *Cast Copper Alloys*—Cast copper alloy fittings shall be made from material meeting the requirements of one of the following:

(1) Specification B61, Copper Alloy UNS C92200,

(2) Specification B62, Copper Alloy UNS No. C83600, or

(3) Specification B584, Copper Alloy UNS Nos. C84400, C83800, or C87850.

5.2.2 *Machined Brass*—Machined brass fittings shall be made from material meeting the requirements of one of the following:

(1) Specification B16/B16M, Copper Alloy UNS No. C36000,

(2) Specification B140/B140M, Copper Alloy UNS No. C31400,

TABLE 1 PEX Tubing Material Designation Code Cells

Property	Standard	0	1	2	3	6	8
Chlorine Resistant	...	Not applicable	...	...	...	...	...
Minimum UV Resistance	F2657	Not tested or rated	1 month	3 months	6 months	...	...
HDS for water at 73 °F, psi	D2837	...	...	...	...	630	800

(3) Specification B371/B371M, Copper Alloy UNS No. C69300, or

(4) Specification B967/B967M, Copper Alloy UNS No. C49260 or C49340.

5.2.3 *Forged Brass*—Forged brass fittings shall be made from material meeting the requirements of Specification B283, Copper Alloy UNS Nos. C27450, C35330, C36500, C37700, C46400, C48600, C49260, C49340, or C69300.

5.2.4 *Stainless Steel*—Stainless steel fittings shall be made from material meeting requirements of one of the following:

(1) Specification A312/A312M, stainless steel alloy 304, 304L, 316 or 316L, (UNS Nos. S30400, S30403, S31600 or S31603),

(2) Specification A269/A269M, stainless steel alloy 304, 304L, 316, 316L (UNS Nos. S30400, S30403, S31600 or S31603), or

(3) Specification A276/A276M, Stainless steel alloy 304, 401L, 316, or 316L (UNS Nos. S30400, S30403, S31600 or S31603).

6. Requirements

6.1 *Workmanship*—The tubing shall be homogeneous throughout and free of 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 *Out-of Roundness*—The maximum out-of roundness requirements, shown in Table 2 for tubing, apply to the average measured diameter. Tubing shall be measured prior to coiling.

6.3 *Dimensions and Tolerances:*

6.3.1 *Outside Diameters*—The outside diameters and tolerances of the tubing including the layers shall be as shown in Table 2, when measured in accordance with 7.4 and 7.4.1.

6.3.2 *Total Wall Thickness*—The total wall thickness and tolerances (including an optional barrier layer) shall be as shown in Table 3, when measured in accordance with 7.4 and 7.4.2. This specification covers PEX tubing in two sizes, ⅝ NTS (nominal tubing size) and ⅞ NTS. The minimum wall thickness is 0.070 in. (1.78 mm), as shown in Table 3.

6.3.2.1 *Barrier Layer*—Tubing that incorporates an optional middle or outer barrier layer shall meet the minimum total wall thickness (PEX layer plus barrier layer) and tolerances requirements as specified in Table 3.

6.3.2.2 *Alternate Minimum PEX Wall Layer Thickness*—For this specification and at the option of the tubing manufacturer, it shall be acceptable for the minimum wall thickness of the PEX layer to be reduced by using the alternate minimum PEX wall thickness and tolerance values stated in Table 3. The total wall thickness, inclusive of all layers, shall still conform to the total wall thickness dimensions and tolerances.

6.3.2.3 For tubing where the base PEX wall thickness falls below 0.070 in. (1.78 mm), the tubing manufacturer shall demonstrate hydrostatic strength equivalency (HSE) between the reduced PEX wall oxygen barrier tube and a non-barrier tube made from the same PEX formulation. HSE evaluation shall be conducted in accordance with 7.13. Tubing requiring HSE evaluation shall be marked in accordance with 9.2.10 specifically stating "HSE-DR."

6.4 *Density*—When determined in accordance with 7.5, the crosslinked polyethylene tubing material shall have a minimum density of 0.926 g/cm^3.

6.5 *Hydrostatic Sustained Pressure Strength*—The tubing and fittings (tested as assemblies) shall not fail, balloon, burst, or weep as defined in Test Method D1598, at the test pressures shown in Table 4 when tested in accordance with 7.6.

6.6 *Hydrostatic Burst Pressure*—The minimum burst pressure for PEX tubing and fittings (tested as assemblies) shall be as shown in Table 5, when determined in accordance with 7.7.

6.7 *Environmental Stress Cracking*—There shall be no loss of pressure in the tubing, when tested in accordance with 7.8.

6.8 *Degree of Crosslinking*—When tested in accordance with 7.9, the degree of crosslinking for PEX tubing material shall be within the range from 65 to 89 % inclusive. Depending on the process used, the following minimum percentage

TABLE 2 Outside Diameters and Tolerances for 0.070 in.-Wall PEX Tubing

Nominal Tubing Size		Average Outside Diameter		Tolerances for Average Diameter		Out-of-Roundness^A	
		in.	(mm)	in.	(mm)	in.	(mm)
⅝	DR 10.7	0.750	(19.05)	±0.004	(±0.10)	0.016	(0.40)
⅞	DR 14.3	1.000	(25.40)	±0.004	(±0.10)	0.016	(0.40)

^{A} The Out-of-Roundness specification applies only to tubing prior to coiling.

TABLE 3 Wall Thickness and Tolerances for 0.070 in. -Wall PEX Tubing for Radiant Heating^A

Nominal Tubing Size (NTS)		Minimum Total Wall Thickness (See below for minimum wall thickness requirements for tubing)		Tolerance (For PEX tubing or PEX tubing with an optional barrier layer)	
		in.	mm	in.	mm
⅝	DR 10.7	0.070	(1.78)	+0.010	(+0.25)
⅞	DR 14.3	0.070	(1.78)	+0.010	(+0.25)

Nominal Tubing Size (NTS)		Minimum PEX Wall Thickness for Tubing with Barrier Layer	
⅝	HSE DR 10.7	0.065	(1.65)
⅞	HSE DR 14.3	0.065	(1.65)

^{A} 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. The minimum wall thickness for tubing sizes below ⅞ in. (22.2 mm) is 0.070 in. (1.78 mm).

TABLE 4 Minimum Hydrostatic Sustained Pressure Requirements for 0.070 in.-Wall PEX Tubing and Fittings for Radiant Heating

Nominal Tubing Size		Pressure Required for Test, psi^A (MPa)			
		73.4 °F	(23 °C)	180 °F	(82.2 °C)
⅝	DR 10.7	268	(1.85)	159	(1.10)
⅞	DR 14.3	197	(1.36)	117	(0.81)

^{A} The fiber stresses used to derive these test pressures are:
at 73.4 °F (23.0 °C) 1300 psi (8.96 MPa).
at 180 °F (82.2 °C) 770 psi (5.31 MPa).

TABLE 5 Burst Pressure Requirements for 0.070 in.-Wall PEX Tubing and Fittings for Radiant Heating

Nominal Tubing Size		Pressure Required for Test, psi[A] (MPa)			
		73.4 °F	(23 °C)	180 °F	(82.2 °C)
⅝	DR 10.7	391	(2.70)	175	(1.21)
⅞	DR 14.3	288	(1.98)	129	(0.89)

[A] The fiber stresses used to derive these test pressures are:
at 73.4 °F (23.0 °C) 1900 psi (13.10 MPa),
at 180 °F (82.2 °C) 850 psi (5.86 MPa).

crosslinking values shall be achieved: 70 % by peroxides, 65 % by Azo compounds, 65 % by electron beam, or 65 % by silane compounds.

6.8.1 *Barrier Layer*—For tubing with a barrier layer, the degree of crosslinking of the PEX material, excluding the barrier layer, shall be in accordance with 6.8.

6.9 *Stabilizer Functionality*—Stabilizer Functionality shall be tested in accordance with 7.10.

6.10 *Bent Tube Hydrostatic Sustained Pressure Strength:*

6.10.1 *General*—PEX tubing bent by using the technique described in X3.2.4 shall meet the requirements in 6.10.2.

6.10.2 Cold-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 minimum hydrostatic sustained pressure strength requirements for 120 °F and a fiber stress of 1000 psi when tested in accordance with 7.6. The bend length and bend angle is kept throughout the testing period by rigid secures immediately outside the bend.

NOTE 4—⅝ NTS and ⅞ NTS PEX tubing with a 0.070 in. wall thickness may be more susceptible to mechanical damage, crushing, pinching, or kinking while bending than SDR 9 PEX tubing.

6.11 *Tubing Material Designation Code*—The tubing meeting the requirements of this specification shall be designated PEX followed by four digits per 3.2.9.

6.12 *Fittings:*

6.12.1 Fittings shall be compatible with tubing made to the requirements of this standard.

6.12.2 *Thermocycling*—Fittings, assembled using the 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 7.11.

6.13 *Excessive Temperature*—Pressure Capacity:

6.13.1 *Excessive Temperature Hydrostatic Sustained Pressure*—Tubing and fittings shall not fail as defined in Test Method D1598 in less than 30 days (720 h) when tested in accordance with 7.12.

6.14 *Barrier Layer Adhesion Test*—Tubing that incorporates an optional middle or outer layer shall not show any delamination when tested in accordance with Specification F1281.

6.15 *Permeation Requirements*—If a barrier layer is used, the PEX tubing with oxygen barrier layer shall meet the oxygen permeation requirements of this specification. Oxygen permeation shall be less than 4.588×10^{-4} grains / ($ft^2 \times$ day) at 104 °F [0.32 mg / $m^2 \times$ day) at 40 °C] when conditioned and tested in accordance with ISO 17455, with the following additional sample preparation—wrap 10 % of the required sample length around a core cylinder of radius equal to the manufacturer's specified minimum bending radius.

7. Test Methods

7.1 *Conditioning*—Condition the specimens at 73.4 ± 3.6 °F (23 ± 2 °C) and 50 ± 10 % 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 ± 3.6 °F (23 ± 2 °C) and 50 ± 10 % 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, as agreed upon by the purchaser and the seller, shall be selected and tested to determine conformance with this specification (see Practice). In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

7.3.1 *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 tubing that is at least one tubing diameter away from an end closure.

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 If there is an optional barrier layer, make measurements of the layer or layers using either a video microscope, a microscope with 0.001 in. (0.025 mm) graduation or optical comparator to determine the maximum and minimum values.

7.5 *Density*—Determine density in accordance with Test Method D1505 or Test Methods D792 using three specimens taken from tubing after processing and crosslinking.

7.6 *Hydrostatic Sustained Pressure Test*—Select the test specimens (assemblies) at random. Test individually with water at the controlled temperatures and under the pressures given in Table 4, specimens of tubing, each specimen at least ten times the diameter in length, but not less than 10 in. (25.4 cm) or more than 3 ft (91.4 cm) between end closures and containing the permanent marking on the tubing. Test six specimens at each temperature. Condition the specimens for at least 2 h to

within ±3.6 °F (±2 °C) of the specified test temperatures. Maintain the specimens at the pressures indicated for the appropriate temperatures for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi (±0.070 MPa). Maintain the test temperatures within ±3.6 °F (±2 °C) of the specified temperature. Test in accordance with Test Method D1598 except maintain the pressure at the values given in Table 4 for 1000 h. Failure of two of the six specimens tested at either temperature constitutes failure in the test. Failure of one of six specimens tested at either temperature is cause for retest of six additional specimens at that temperature. Failure of one of six specimens tested at either temperature in retest constitutes failure in the test. Failure of the tubing shall be defined in accordance with Test Method D1598, namely:

7.6.1 *Failure*—Any continuous loss of pressure resulting from the transmission of the test liquid through the body of the specimen under test.

7.6.2 *Ballooning*—Any abnormal localized expansion of a tubing specimen while under internal hydraulic pressure.

7.6.3 *Bursting*—Failure by a break in the tubing with immediate loss of test liquid and continued loss at essentially no pressure.

7.6.4 *Seepage or Weeping*—Failure that occurs through essentially microscopic breaks in the tubing wall, frequently only at or near the test pressure.

NOTE 5—At lower pressures, the pipe may carry liquids without evidence of loss of liquids.

7.6.5 *Delamination*—Failure by separation of the layers visible to the unaided eye.

7.7 *Hydrostatic Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599. The time of testing of each specimen shall be between 60 and 70 s. The pressure values are given in Table 5.

7.8 *Environmental Stress Cracking Test*—Use six randomly selected 10-in. (250-mm) long specimens for this test. Make a notch on the inside of the tubing wall in the axial direction. The notch depth shall be 10 % of measured minimum wall thickness and the notch length 1 in. (25 mm). Use a sharp blade mounted in a jig to make this imperfection. 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 diameter away from end closures. Fill the tubing with the test medium which is 5 % "Igepal CO-630"[6]mixed with 95 % of untreated water. The test is then made in accordance with 7.6, under the pressures given in Table 4, except maintain the pressure for 100 h.

NOTE 6—Studies have shown that there are environmental concerns regarding the disposal of Nonylphenoxy poly(ethyleneoxy) ethanol CAS 68412-54-4 for example, Igepal-630[6]. Users are advised to consult their supplier or local environmental office and follow the guidelines provided for the proper disposal of this chemical.

7.9 *Degree of Crosslinking*—Place a PEX tubing sample in a lathe with automatic feeding. Shave a strip that consists of the full wall thickness, consisting only of the PEX material–barrier or bonding layer material shall not be in this shaved strip of PEX for the degree of crosslinking test. The strip thickness shall be approximately 0.004 in. (0.1 mm), which is obtained by setting the lathe feeding accordingly. Test the specimens in accordance with Test Methods D2765, Method B, with the only deviation: test specimen preparation. For the purpose of this specification, degree of crosslinking (V) is defined as 100 % minus extract percent equals V.

NOTE 7—This method provides a test method for measuring the average degree of crosslinking over the PEX tube wall thickness. That, however, does not mean that the degree of crosslinking is allowed to vary outside the limits for the grade in question at any part of the tubing. In case of disagreement, strips of the same thickness, 0.004 in. (0.1 mm), can be taken in tangential, axial, or radial direction at any angle section or wall thickness depth, or both, etc. to measure the degree of crosslinking excluding barrier layer.

7.10 *Stabilizer Functionality*—The functionality of a stabilizer in a specific PEX compound shall be verified by hydrostatic testing of pipe made from the compound. Test six pipe samples continuously for 3000 h at a hoop stress of 0.70 MPa at 120 °C, or for 8000 h at a hoop stress of 2.8 MPa at 110 °C. This test is used to demonstrate the specific compound's ability to withstand long term temperature conditions set forth elsewhere in this standard.

7.10.1 *Procedure*—The test procedure shall be conducted in accordance with Test Method D1598 or ISO 1167. Test six (6) samples at one of the temperature conditions in 7.10. The internal medium is water the external medium is air. Failure of any one of the specimens constitutes failure of the test.

7.11 *Thermocycling:*

7.11.1 *Summary of Test Method*—This test method describes a pass-fail test for thermally cycling PEX 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 PEX tubing and fittings intended for continuous use up to and including 180 °F (82 °C).

7.11.2 *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.

7.11.3 *Apparatus*—A nitrogen or air source capable of maintaining a nominal internal pressure of 50 ± 5 psi (0.35 ± 0.035 MPa) on the specimens is required. The immersion system shall consist of two water reservoirs controlled at 60 ± 4 °F (16 ± 2 °C) and 180 ± 4 °F (82 ± 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 8—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

[6] This method is based on the use of "Igpal Co-630," a trademark for a nonylphenoxypoly (ethyeneoxy) ethanol, which may be obtained from GAF Corp., Dyestuff and Chemical Div., 140 W. 51st St., New York, NY 10020.