**Designation: ~~F3253 – 23~~ F3253 – 24**

An American National Standard

# Standard Specification for Crosslinked Polyethylene (PEX) Tubing with Oxygen Barrier for Hot- and Cold-Water Hydronic Distribution Systems[1]

This standard is issued under the fixed designation F3253; 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 requirements, test methods, and marking requirements for crosslinked polyethylene (PEX) tubing with a polymeric oxygen barrier layer, made in one standard dimension ratio (SDR 9), and distribution system components intended for hydronic heating and cooling applications up to and including a maximum working temperature of 200 °F (93 °C).

1.1.1 Components are comprised of tubing, fittings, valves, and manifolds. Tubing made to this specification incorporates a single outer or middle wall oxygen barrier layer intended for inhibiting the transmission or permeation of oxygen through the tubing wall. Requirements and test methods are included for materials, workmanship, tubing dimensions and tolerances, burst pressure, sustained pressure, excessive temperature and pressure, thermo-cycling, bent tube, oxidative resistance, layer adhesion, UV resistance, oxygen permeation, and fitting pull-out strength tests. The components covered by this specification are intended for use in residential and commercial hydronic heating and cooling systems. Requirements for potable water applications are outside the scope of this specification.



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 *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

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

[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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[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.

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

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 (Withdrawn 2024)[3]
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2749 Symbols for Dimensions of Plastic Pipe Fittings
D2765 Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
F412 Terminology Relating to Plastic Piping Systems
F876 Specification for Crosslinked Polyethylene (PEX) Tubing
F877 Specification for Crosslinked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems
F1281 Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe
F1588 Test Method for Constant Tensile Load Joint Test (CTLJT)
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
F1865 Specification for Mechanical Cold Expansion Insert Fitting With Compression Sleeve for Cross-linked Polyethylene (PEX) Tubing (Withdrawn 2018)[3]
F2023 Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water
F2080 Specification for Cold-Expansion Fittings with Metal Compression-Sleeves for Crosslinked Polyethylene (PEX) Pipe and SDR9 Polyethylene of Raised Temperature (PE-RT) Pipe
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
F2434 Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Cross-linked Polyethylene/Aluminum/Cross-linked Polyethylene (PEX-AL-PEX) Tubing
F2657 Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing
F2735 Specification for Plastic Insert Fittings For SDR9 Cross-linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing
F3347 Specification for Metal Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing
F3348 Specification for Plastic Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

2.2 *AWWA Standard:*[4]
Manual M-11, Steel Pipe Design and Installation

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

2.4 *ISO Standards:*[6]
ISO 1167 Thermoplastics pipes, fittings and assemblies for the conveyance of fluids -- Determination of the resistance to internal pressure -- Part 1: General method
ISO 13760 Plastics pipes for the conveyance of fluids under pressure -- Miner's rule -- Calculation method for cumulative damage
ISO 17455 Plastics piping systems — Multilayer pipes — Determination of the oxygen permeability of the barrier pipe
ISO R161-1690 Pipes of Plastic Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part 1, Metric Series

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

2.6 *NSF Standard:*[7]
NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials

[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.
[5] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/
[6] 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.
[7] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, http://www.nsf.org.

2.7 *PPI Standard:*[8]

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), Minimum Required Strength (MRS) Ratings, and Categorized Required Strength (CRS) 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 The terminology used in this specification is in accordance with Terminology F412, Terminology D1600, and Symbols D2749, unless otherwise specified. The abbreviation for crosslinked polyethylene is PEX.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *barrier layer*—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 *hydrostatic design basis (HDB)*—As defined by Terminology F412 is 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.

3.2.2.1 *Discussion*—

A voluntary listing of HDB, and HDS values are contained in PPI publication PPI TR-4.

3.2.3 *hydrostatic design stress (HDS)*—As defined by Terminology F412 is 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; $HDS=HDB\times DF$. For this specification, the design factor is less than or equal to 0.50.

3.2.4 *hydrostatic strength equivalency (HSE)*—a pressure testing evaluation methodology where hydrostatic testing is conducted on PEX tubing that is constructed with a barrier layer or layers 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 or layers reduce 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 that required for SDR 9.0.

3.2.4.1 *Discussion*—

HSE testing is conducted to confirm that the pressure rating of the PEX tubing having a barrier layer or layers as described herein is at least equal to comparable SDR 9.0 PEX tubing that does not have a barrier layer or layers. When PEX tubing has a barrier layer(s) that does not reduce the thickness of the HDB-rated PEX material below that required for SDR 9.0, it is not necessary to conduct HSE testing because pressure rating is determined using the ISO equation (3.2.6).

3.2.5 *HSE-SDR 9*—an identifying term for the tubing where the minimum PEX wall thickness falls outside the calculated SDR 9 values yet the tubing as constructed meets the pressure rating requirements of this standard as demonstrated by HSE evaluation testing.

3.2.6 *ISO equation and pressure rating (PR)*—The relationship between dimensions, hydrostatic design basis, hydrostatic design stress, and pressure rating as defined by Terminology F412 is illustrated as follows specific to this specification.

The following is commonly referred to as the ISO equation (See ISO R161-1690.) :

$$S = P(OD - t)/2t \text{(For outside diameter controlled pipe)} \quad (1)$$

where:

$S$ = hoop stress,
$P$ = pressure,
$OD$ = average outside diameter,
$t$ = minimum wall thickness

The pressure rating (PR) and HDS/HDB are related by the following equation:

[8] Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825 Irving TX, 75062. http://www.plasticpipe.org

$$PR = 2(HBD)(DF)/(SDR - 1) = 2(HDS)/(SDR - 1) \quad (2)$$

(being specific to this specification with DF=0.50 and SDR 9)

$$PR = 2(HDB)(0.50)/(9 - 1) = 2(HDS)/8 \quad (3)$$

Example: PEX with HDB of 800 PSI at 180 °F made according to this specification to SDR 9

$$PR = 2(800)(0.50)/(9 - 1) = 100\text{PSI} \quad (4)$$

3.2.7 *manifold*—an appurtenance that has at least one inlet and multiple outlets

3.2.8 *standard dimension ratio (SDR)*—the ratio of outside diameter to wall thickness as defined by Terminology F412 except this standard uses the minimum total wall thickness, inclusive of layers, to establish SDR. When the total wall thickness calculated by the given formula is less than 0.070 in. (1.78 mm) then the total wall thickness is arbitrarily increased to 0.070 in. except for NTS 5⁄16 and smaller which are prescriptively assigned.

3.2.9 *standard thermoplastic tubing materials designation code*—This material designation code consists of the abbreviation for the type of plastic (PEX) followed by four Arabic digits that describe those properties in accordance with applicable ASTM standards and as shown in Table 1. This material designation code solely addresses the PEX material and does not address any other polymeric materials which might be used in the construction of oxygen barrier tubing.

3.2.9.1 *Discussion*—

The first digit is for chlorine resistance. Since this standard is specific to hydronic distribution systems, chlorine resistance is not a mandatory requirement of this application and the default "0" is used if oxidative stability is evaluated only per 6.1.9.1 (stabilizer functionality). If oxidative stability is evaluated per 6.1.9.2 (chlorine resistance), this digit is defined by Specification F876 as follows:

*(1)* A digit "0" indicates that the PEX tubing either has not been tested for chlorine resistance or that the PEX tubing does not meet the minimum requirement for chlorine resistance.
*(2)* A digit "1" indicates the PEX tubing has been tested and meets the requirement of 6.1.9.2 for minimum chlorine resistance at the end use condition of 25 % at 140 °F (60 °C) and 75% at 73 °F (23 °C).
*(3)* A digit "2" is reserved for future application.
*(4)* A digit "3" indicates that the PEX tubing has been tested and meets the requirement of 6.1.9.2 for minimum chlorine resistance at end use condition of 50 % at 140 °F and 50% at 73 °F.
*(5)* A digit "4" is reserved for future application.
*(6)* A digit "5" indicates that the PEX tubing has been tested and meets the requirement of 6.1.9.2 for minimum chlorine resistance at end use conditions of 100 % of the time at 140 °F.

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 this specification it is one of the classification digits listed in Table 1 for the Nominal Exposure Time Period from Table 1 in Test Method F2657 where the decreased average failure time from 10.3 of Test Method F2657 is less than or equal to 21%. Alternately, the second digit may 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 7.2.10 Stabilizer Functionality.

*(1)* The 21% pass/fail criteria originates from the statistical analysis of an aggregate of data sets generated using Test Method F2023 and represents the mean Lower Predictive Limit (95% two sided) compared to the expected failure times based on three stress levels at each of three temperatures. Thus, this value represents the limit for statistical differentiation in failure times using Test Method F2023 at the 95% confidence level (2 sided). This research was conducted for the Plastics Pipe Institute in 2005.[9]

**TABLE 1 Material Designation Code Cells**

| Property | Standard | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorine Resistance | F2023 | Not tested or rated | (See Specification F876) 25 % at 140 °F 75 % at 73 °F | Reserved | (See Specification F876) 50 % at 140 °F 50 % at 73 °F | (See Specification F876) Reserved | (See Specification F876) 100 % at 140 °F | ... | ... | ... | ... |
| Minimum UV Resistance | F2657 | Not tested or rated | 1 month | 3 months | 6 months | ... | ... | ... | ... | ... | ... |
| HDS for water at 73 °F | ... | ... | ... | ... | ... | ... | ... | 630 | ... | 800 | ... |

[9] PPI Technical Literature, Final Report – Proposal for the Evaluation of the Chlorine Resistance of UV Exposed PEX Pipe.

The UV resistance of the PEX material is demonstrated on representative pipe samples for the original validation of pipe made from a particular PEX material formulation, that material formulation being the combination of PEX base resin and its respective additives.

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 consists of the three letters "PEX" and four digits. See Fig. 1. For example ASTM F3253 PEX tubing marked with the material designation code of PEX 0106 is a PEX tubing meeting the minimum stabilizer functionality requirement, having a UV resistance of 1 month, and having an HDS for water of 630 psi at 73 °F (HDB of 1250 psi)..

3.2.10 *system components*—tubing, fittings, valves and manifolds

## 4. Classification

4.1 *Tubing:*

4.1.1 *General:*

4.1.1.1 This specification covers one PEX tubing material having pressure ratings for water at three temperatures. The pressure ratings decrease as the temperature is increased.

4.1.1.2 This specification covers PEX tubing in one standard dimension ratio (SDR 9) for nominal diameters NTS ⅝ and larger, and with specified wall thicknesses for smaller diameters. Tubing pressure ratings are uniform for all nominal tubing sizes.

*(1)* All tubing sizes in this standard are dimensionally compatible with PEX fittings that comply with 6.2.2.

*(2)* All oxygen barrier tubing sizes in this standard are pressure rated equivalent to SDR 9.0 PEX tubing. Tubing that has PEX material minimum wall thickness equal to or greater than the minimum wall thickness calculated for SDR 9.0 is pressure rated as SDR 9.0 using the ISO equation (3.2.6), and is marked "SDR 9". Tubing having barrier layer(s) that has PEX material minimum wall thickness that is less than the minimum wall thickness calculated for SDR 9.0 is pressure rated using hydrostatic strength equivalency (HSE) testing (7.3.13), and is marked "HSE-SDR 9".

4.2 *Fittings*—This specification classifies fittings including manifolds with integral fittings and valves, and valves with integral fittings, intended for use in systems with PEX tubing, by a maximum continuous use temperature that shall be 200 °F (93 °C) and by nominal sizes from NTS ⅛ through NTS 6 on the basis of resistance to hydrostatic burst pressure, hydrostatic sustained pressure, excessive temperature/pressure capability, thermocycling, and by pull-out strength. Fittings shall be compatible with tubing made to the requirements of this specification.

## 5. Materials

5.1 *General*—PEX oxygen barrier tubing systems shall use crosslinked polyethylene tubing as described in this specification.

5.2 *Tubing Materials:*

5.2.1 PEX tubing, exclusive of oxygen barrier and bonding layers, shall be made from polyethylene compounds which have been crosslinked by peroxides, 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 stress ratings equal to or better than those shown in Table 2, when determined in accordance with Test Method D2837 and procedures no less restrictive

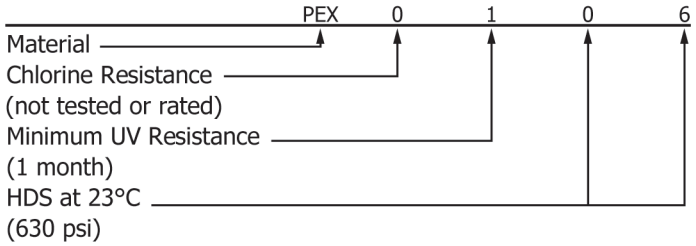


**FIG. 1 Standard Thermoplastic Tubing Materials Designation Code**

**TABLE 2 Hydrostatic Design Stresses and Pressure Ratings for SDR 9 PEX Tubing for Water at Different Temperatures**

| Rated Temperature | | Hydrostatic Design Stress | | Pressure Rating for Water | |
|---|---|---|---|---|---|
| °F | (°C) | psi | (MPa) | psi | (MPa) |
| 73 | (23) | 630 | (4.34) | 160 | (1.10) |
| 180 | (82) | 400 | (2.76) | 100 | (0.69) |
| 200 | (93) | 315 | (2.17) | 80 | (0.55) |

than those of PPI TR-3. Tubing inclusive of layers shall also meet the requirements of PPI TR-3.[10] See Appendix X1 for additional information on PPI hydrostatic stress ratings.

5.2.2 The oxygen barrier layer shall be specified by the tubing manufacturer.

NOTE 1—Typically the oxygen barrier layer is made from EVOH (Ethylene vinyl alcohol). EVOH copolymer is defined by the mole % ethylene content: lower ethylene content grades have higher oxygen barrier properties. Polymeric oxygen barrier layer material other than EVOH shall be acceptable provided that they are compatible with the PEX material and the bonding/tie layer(s) and also meets all of the requirements of this specification.

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

5.2.4 *Tubing Material Designation*—Tubing meeting the requirements of this specification shall be designated

5.3 Fitting and manifold materials, including fittings and manifolds with integral valves, shall meet the applicable material requirements of at least one of the Specifications F1807, F1960, F2080, F2159, F2434, F2735, F3347, or F3348.

## 6. Requirements

6.1 *Tubing:*

6.1.1 *Workmanship*—The tubing shall be 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.

6.1.2 *Out-of Roundness*—The maximum out-of roundness requirements, shown in Table 3 for tubing, apply to the average,

**TABLE 3 Outside Diameters and Tolerances for Oxygen Barrier Tubing**

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

[10] PPI Technical Report TR-3, PPI Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), Minimum Required Strength (MRS) Ratings, and Categorized Required Strength (CRS) for Thermoplastic Piping Materials or Pipe.

measured diameter. Tubing shall be measured prior to coiling.

6.1.3 *Dimensions and Tolerances:*

6.1.3.1 *Outside Diameters*—The outside diameters and tolerances of the tubing inclusive of layers shall be per Table 3, when measured in accordance with 7.3.3.1.

6.1.3.2 *Total Wall Thickness*—The total wall thickness and tolerances shall be per Table 4, when measured in accordance with 7.3.3.2.

*(1) Layers*—Tubing made according to this specification incorporating an oxygen barrier layer shall meet the total wall thickness and tolerances requirements as specified in Table 4. In addition, the oxygen barrier layer(s) shall not result in the reduction of the PEX material wall(s) below that specified in Table 5. In the case of tubing with a middle layer, the base PEX material wall thickness shall be the sum of the inner and outer base PEX material wall thicknesses exclusive of barrier and bonding/tie layers. For tubing where the base PEX wall thickness falls below the dimensions given in Table 4 and also results in a calculated SDR greater than 9.0, 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 not be required on sizes smaller than ½ nominal tubing size (NTS) as wall thickness minimums are not a function of SDR as the calculated SDR is less than 9.0 for ⅜ NTS and smaller sizes even when using the minimum PEX wall dimensions given in Table 5. HSE evaluation shall be conducted in accordance with 7.3.13. Tubing requiring HSE evaluation shall be marked in accordance with 10.2.5 specifically stating “HSE-SDR 9”.

6.1.4 *Density*—When determined in accordance with 7.3.4, the PEX tubing material (exclusive of barrier and bonding/tie layers) shall have a minimum density of 0.926 g/cm$^3$.

6.1.5 *Hydrostatic Sustained Pressure Strength*—The tubing shall not fail, balloon, burst, or weep as defined in Test Method D1598, at the test pressures shown in Table 6 when tested in accordance with 7.3.5.

6.1.6 *Hydrostatic Burst Pressure*—The minimum burst pressure for PEX oxygen barrier tubing shall be as shown in Table 7, when determined in accordance with 7.3.6.

6.1.7 *Environmental Stress Cracking Resistance (ESCR)*—There shall be no loss of pressure in the tubing, when tested in accordance with 7.3.7.

6.1.8 *Degree of Crosslinking*—When tested in accordance with 7.3.8, the degree of crosslinking for PEX tubing material shall be



**TABLE 4 Wall Thickness and Tolerances for Nominal PEX SDR 9[A] Oxygen Barrier Tubing**

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

[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.
[B] For nominal tubing sizes of ½ and below, wall thickness minimums are not functions of SDR.

**TABLE 5 Minimum PEX Wall Thickness[A]**

| Nominal Tubing Size | Minimum PEX Wall Thickness | |
|---|---|---|
| NTS | in. | (mm) |
| ⅛ | 0.042[B] | (1.07)[B] |
| ¼ | 0.057[B] | (1.45)[B] |
| 5/16 | 0.059[B] | (1.50)[B] |
| ⅜ | 0.065[B] | (1.65)[B] |
| ½ | 0.065[C] | (1.65)[C] |
| ⅝ | 0.078[C] | (1.98)[C] |
| ¾ | 0.092[C] | (2.34)[C] |
| 1 | 0.120[C] | (3.05)[C] |
| 1¼ | 0.148[C] | (3.76)[C] |
| 1½ | 0.176[C] | (4.47)[C] |
| 2 | 0.231[C] | (5.87)[C] |
| 2½ | 0.287[C] | (7.29)[C] |
| 3 | 0.342[C] | (8.69)[C] |
| 3½ | 0.398[C] | (10.11)[C] |
| 4 | 0.453[C] | (11.51)[C] |
| 4½ | 0.509[C] | (12.93)[C] |
| 5 | 0.564[C] | (14.33)[C] |
| 6 | 0.676[C] | (17.17)[C] |

[A]The minimum PEX wall is the lowest measured wall thickness of the pipe, excluding any non-PEX layers, at any cross section. The maximum permitted wall thickness on the PEX wall is only limited by the dimensions stated in Table 4.
[B]For these sizes the minimum PEX walls are not functions of SDR and are not subject to HSE evaluation testing as the calculated SDR is less than 9.0.
[C]HSE evaluation testing shall be conducted for these sizes to confirm that tubing pressure ratings are equal to or greater than the pressure ratings established in this standard for SDR 9.0 tubing. Tube constructions evaluated per the HSE method shall be appropriately marked per section 10.2.4 specifically stating "HSE-SDR 9"



within the range from 65 to 89 % inclusive. Depending on the process used, the following minimum percentage crosslinking values shall be achieved: 70 % by peroxides, 65 % by electron beam, or 65 % by silane compounds. For this specification, the degree of cross-linking of the PEX material excluding the layer(s) shall be tested in accordance with 7.3.8.

6.1.9 *Oxidative Stability*—Tubing made according to this specification shall demonstrate sufficient oxidative stability against the deleterious effects of long-term thermal degradation such as those encountered in hydronic heating systems. Therefore tubing shall meet the performance requirements of either the Stabilizer Functionality Test or the Oxidative Stability (Chlorine) Test in accordance with 6.1.9.1 or 6.1.9.2:

6.1.9.1 *Stabilizer Functionality*—Stabilizer Functionality shall be tested in accordance with 7.3.10.

6.1.9.2 *Oxidative Stability in Hot-Chlorinated Water*—Tubing shall have a minimum extrapolated time-to-failure of 50 years when tested and evaluated in accordance with 7.3.9. If this method is used to evaluate oxidative stability of the tubing, the standard thermoplastic tubing materials designation code for the 1st digit shall be a minimum of "1", or optionally "3", or "5" per the requirements of Specification F876. (See 3.2.9.)

6.1.10 *Oxygen Permeation*—Tubing made according to this specification shall meet the oxygen permeation requirements of this standard. Oxygen permeation shall be less than $4.588x10^{-4}$ grains/($ft^2$ *day) at 104 °F (0.32 mg/($m^2$*day) at 40 °C) when tested in accordance with ISO 17455 using either the dynamic (Method I) or static (Method II) methods. Testing at temperatures higher or lower than 40 ºC is optional for the purposes of this specification. Samples shall be conditioned in accordance with 7.3.11.

6.1.11 *Adhesion Test*—Tubing that incorporates an optional middle or outer layer shall not show any delamination when tested in accordance with the adhesion test of Specification F1281.

6.1.12 *Bent Tube Hydrostatic Sustained Pressure Strength:*

6.1.12.1 *General*—PEX oxygen barrier tubing, up to and including NTS 1, can be installed cold-bent provided that 6.1.12.2 requirements are met.

NOTE 2—PEX tubing, larger than NTS 1 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 6 times the outside diameter is needed. The test procedures in 6.1.12.2 are intended to evaluate PEX tubing installed in tight bend applications in accordance with the installation procedure in X2.3.4. This application applies to tubing up

**TABLE 6 Minimum Hydrostatic Sustained Pressure Requirements for PEX Nominal SDR 9 Tubing**

| Nominal Tubing Size | Pressure Required for Test psi[A] , MPA | | | | | |
|---|---|---|---|---|---|---|
| NTS | 73 °F | (23 °C) | 180 °F | (82 °C) | 200 °F | (93 °C) |
| ⅛ | 595 | (4.10) | 355 | (2.45) | 300 | (2.07) |
| ¼ | 515 | (3.55) | 305 | (2.10) | 260 | (1.79) |
| 5⁄16 | 455 | (3.13) | 270 | (1.86) | 225 | (1.55) |
| ⅜ | 425 | (2.93) | 250 | (1.72) | 210 | (1.45) |
| ½ | 330 | (2.27) | 195 | (1.34) | 165 | (1.14) |
| ⅝ and larger | 325 | (2.24) | 190 | (1.31) | 165 | (1.14) |

[A] The fiber stress for SDR9 PEX tubing used to derive this test pressure is:
at 73.4 °F (23 °C) 1300 psi (8.96 MPa).
at 180 °F (82 °C) 770 psi (5.31 MPa).
at 200 °F (93 °C) 650 psi (4.48 MPa).

**TABLE 7 Burst Pressure Requirements for Water at Different Temperatures for PEX SDR 9 Oxygen Barrier Tubing**

| Nominal Tubing Size | Minimum Burst Pressures at Different Temperatures psi, MPa[A] | | | | | |
|---|---|---|---|---|---|---|
| NTS | 73 °F | (23 °C) | 180 °F | (82 °C) | 200 °F | (93 °C) |
| ⅛ | 870 | (5.99) | 390 | (2.69) | 330 | (2.27) |
| ¼ | 752 | (5.18) | 336 | (2.32) | 285 | (1.96) |
| 5⁄16 | 665 | (4.58) | 300 | (2.07) | 250 | (1.72) |
| ⅜ | 620 | (4.27) | 275 | (1.89) | 235 | (1.62) |
| ½ | 480 | (3.31) | 215 | (1.48) | 185 | (1.27) |
| ⅝ and larger | 475 | (3.27) | 210 | (1.45) | 180 | (1.24) |

[A] The fiber stress for SDR9 PEX tubing used to derive this test pressure is:
at 73 °F (23 °C) 1900 psi (13.10 MPa).
at 180 °F (82 °C) 850 psi (5.86 MPa).
at 200 °F (93 °C) 720 psi (4.96 MPa).



to and including 1 in nominal diameter only. This specification, unlike other PEX standards such as Specification F876, does not require hot-bent hydrostatic sustained pressure testing as it is not a practice recommended for oxygen barrier PEX tubing because of a high likelihood of damage to the oxygen barrier layer such as tearing, bunching, and loss of adhesion, after bending.



6.1.12.2 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 180 °F as shown in Table 6 when tested in accordance with 7.3.5. The bend length and bend angle is kept throughout the testing period by rigid secures immediately outside the bend.

6.1.13 *Excessive Temperature Pressure Capability:*

6.1.13.1 In the event of water heating system malfunction, PEX oxygen barrier tubing shall have adequate strength to accommodate short-term conditions of elevated temperature and pressure, 48 h of 210 °F (99 °C). 150 psi (1034 kPa) until repairs can be made.

6.1.13.2 *Excessive Temperature Hydrostatic Sustained Pressure*—Tubing shall not fail as defined in Test Method D1598 in less than 30 days (720 h) when tested in accordance with 7.3.12.

6.2 Fittings, including manifolds and valves with integral fittings:

6.2.1 *Workmanship*—Fittings and the materials that they are made from shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, blisters, voids or other defects that are visible to the naked eye that may affect fitting integrity. All sealing surfaces shall be smooth and free of foreign material.

6.2.2 *Dimensions and Tolerances*—The dimensions and tolerances of fittings shall meet the specific requirements contained in Specifications F1807, F1960, F2080, F2159, F2434, F2735, F3347, F3348 or other recognized PEX fitting approved for use by the tubing manufacturer.

6.2.3 *Corrosion Resistance*—Fittings shall be made from materials that are generally regarded as corrosion resistant.

6.2.3.1 Compliance with this specification requires that fittings defined in Specifications F1807, F1865, F1960, F2080, F2159, F2434, F2735, F3347, F3348 or other recognized PEX fitting specification must meet the Performance requirements of this specification.

6.2.4 *Hydrostatic Burst:*

6.2.4.1 Tubing and fittings (tested as assemblies) assembled using the manufacturer's instructions shall meet the minimum hydrostatic burst requirements shown in Table 7 when tested in accordance with 7.3.6.

6.2.4.2 Manifolds with integral shut-offs (valves) shall be tested with all ports in the full-open or unrestricted position.

*(1)* If the manifold has more than one connection size, the test pressure selected from Table 7 shall be based upon the largest nominal PEX connection.

6.2.5 *Hydrostatic Sustained Pressure Strength:*

6.2.5.1 Tubing and fittings (tested as assemblies) shall meet the minimum hydrostatic sustained pressure strength requirements shown in Table 8 when tested in accordance with 7.3.5.

*(1)* Manifolds with integral shut-off (valves) shall be tested with all ports in the full-open or unrestricted position.

6.2.6 *Thermocycling:*

6.2.6.1 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 7.4.3.

*(1)* Manifolds with integral shut-offs (valves) shall be tested with all ports in the full open or unrestricted position.

6.2.7 *Excessive Temperature—Pressure Capability:*

NOTE 3—In the event of a water heating system malfunction, PEX tubing and system components shall have adequate strength to accommodate short-term conditions, 48 h of 210 °F (99 °C), 150 psi (1034 kPa) until repairs can be made.

6.2.7.1 *Excessive Temperature Hydrostatic Sustained Pressure*—Tubing and system components, when tested as assemblies, shall not fail as defined in Test Method D1598 in less than 30 days (720 h) when tested in accordance with 7.4.5.

*(1)* Manifolds with integral shut-offs (valves) shall be tested with all ports in the full open or unrestricted position.

~~NOTE 4—Tests applicable to assemblies and bends (6.2.4, 6.2.5, 6.2.6, and 6.2.7) are intended to be performance qualification tests and not tests required of each fitting configuration.~~

6.2.8 *Pull-Out Strength:*

6.2.8.1 Fittings used with tubing meeting this specification shall demonstrate sufficient strength to withstand the axial (tensile) forces associated with installation and normal end-use conditions encountered in hydronic systems. Conduct testing in accordance with 7.4.6. Pass/Fail criteria shall be as defined in 7.4.6.

**TABLE 8 Minimum Hydrostatic Sustained Pressure Requirements for SDR9 PEX Oxygen Barrier Tubing and System Component Assemblies[A, B]**

| Nominal Tubing Size NTS | Pressure Required for Test, psi (MPa) 180 °F | (82 °C) |
|---|---|---|
| ⅛ | 355 | (2.45) |
| ¼ | 305 | (2.10) |
| 5/16 | 270 | (1.86) |
| ⅜ | 250 | (1.72) |
| ½ | 195 | (1.34) |
| ⅝ and larger | 190 | (1.31) |

[A]The fiber stress for SDR9 PEX tubing used to derive this test pressure is: 770 psi (5.31 MPa) at 180 °F (82 °C).
[B]Test duration is 1000 h.