



Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems¹

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1. Scope

1.1 This specification covers requirements, test methods, and methods of marking for crosslinked polyethylene plastic hot- and cold-water distribution systems components made in one standard dimension ratio and intended for 100 psi (0.69 MPa) water service up to and including a maximum working temperature of 180°F (82°C). Components are comprised of tubing and fittings. Requirements and test methods are included for materials, workmanship, dimensions and tolerances, hydrostatic sustained pressure strength, thermocycling resistance, fittings, and bend strength. 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 as well as sealed central heating, including under-floor heating systems.

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 the standard. The values stated in parentheses are provided for information only.

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

1.4 The following safety hazards caveat pertains only to the test method portion, Section 7, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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2. Referenced Documents

2.1 ASTM Standards:

- D 618 Practice for Conditioning Plastics for Testing²
- D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure³
- D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings³
- D 1600 Terminology for Abbreviated Terms Relating to Plastics²
- D 1898 Practice for Sampling of Plastics²
- D 2749 Symbols for Dimensions of Plastic Pipe Fittings³
- D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials³
- D 3140 Practice for Flaring Polyolefin Pipe and Tubing³
- F 412 Terminology Relating to Plastic Piping Systems³
- F 876 Specification for Crosslinked Polyethylene (PEX) Tubing³

2.2 ANSI Standards:

- B 36.10 Welded and Seamless Wrought Steel Pipe⁴
- Z 17.1 Preferred Numbers⁴

2.3 AWWA Standard:

- Manual M-11, Steel Pipe Design and Installation⁵

2.4 Federal Standard:

- Fed Std. No. 123 Marking for Shipment (Civil Agencies)⁶

2.5 Military Standard:

- MIL-STD-129 Marking for Shipment and Storage⁶

2.6 NSF Standard:

- Standard No. 14 for Plastic Piping Components and Related Materials⁷

² Annual Book of ASTM Standards, Vol 08.01.

³ Annual Book of ASTM Standards, Vol 08.04.

⁴ Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

⁵ Available from the American Water Works Association, 6666 W. Quincey Ave., Denver, CO 80235.

⁶ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

⁷ Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

3. Terminology

3.1 The terminology used in this specification is in accordance with Terminology F 412, Terminology D 1600, and Symbols D 2749, unless otherwise specified. The abbreviation for crosslinked polyethylene is PEX. Plastic tubing denotes a particular diameter schedule of plastic pipe in which outside diameter of the tubing is equal to the nominal size plus 1/8 in. Plastic pipe outside diameter schedule conforms to ANSI B 36.10.

3.2 *crosslinked polyethylene plastics*—plastics prepared by crosslinking (curing) polyethylene compounds.

3.3 *relation between standard dimension ratio, stress, and internal pressure*—the following expressions, commonly known as the ISO equation, is used to relate standard dimension ratio, stress, and internal pressure for tubing:

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

or

$$2S/P = (D_o/t) - 1$$

where:

S = stress in circumferential or hoop direction, psi (MPa),

P = internal pressure, psi (MPa),

t = minimum wall thickness, in.,

R = standard dimension ratio, SDR, and

D_o = average outside diameter, in.

3.4 *standard dimension ratio (SDR)*—a selected series of numbers in which the average outside diameter to minimum wall thickness dimension ratios are constant for all sizes of tubing in each standard dimension ratio, and which are the ANSI Z 17.1 Preferred Number Series R 10 modified by +1. If the wall thickness calculated by SDR for PEX tubing is less than 0.070 in. (1.78 mm), it shall be arbitrarily increased to 0.070 in. except for sizes 1/4 in. and smaller.

3.5 *standard material designation code*—the crosslinked polyethylene tubing material designation code shall consist of the abbreviation PEX.

4. Materials

4.1 *General*—This specification covers PEX tubing materials as described in Specification F 876.

4.2 *Basic Materials Description*—Crosslinked polyethylene tubing meeting the requirements of this specification are primarily defined by two criteria namely, basic short-term properties and long-term hydrostatic strength, 4.2.1 and 4.2.2 respectively.

4.2.1 *Basic Short-Term Properties*—This specification covers tubing materials meeting the requirements of Specification F 876.

4.2.2 *Long-Term Hydrostatic Pressure Strength*—This specification covers PEX tubing which is further defined on the basis of long-term hydrostatic strength tests (Appendix X1).

4.3 *Certification*—PEX tubing and fittings, used for the distribution of potable water, shall be products approved for that service by the regulatory bodies having such jurisdiction. These products shall be tested for that service by a nationally

recognized and accredited testing laboratory and shall bear the certification mark of the testing agency.

NOTE 2—Further information regarding testing and approval can be obtained from the National Sanitation Foundation or other accredited laboratory.

5. Classification

5.1 *Tubing*—This specification classifies PEX tubing by a single standard dimension ratio that shall be SDR 9, and by a maximum continuous use temperature that shall be 180°F (82°C), and by nominal tubing diameters from 1/8 in. through 2 in.

5.2 *Fittings*—This specification classifies fittings, intended for use in systems with PEX tubing, by a maximum continuous use temperature that shall be 180°F (82°C) and by nominal sizes from 1/8 in. through 2 in. on the basis of resistance to burst pressure, hydrostatic sustained pressure, excessive temperature and pressure, and to failure by thermocycling.

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 *Dimensions and Tolerances:*

6.2.1 *General:*

6.2.1.1 *Tubing*—The PEX tubing shall meet the requirements of Specification F 876. The tolerances for outside diameters are also given in Table 1.

6.2.1.2 *Out-of-Roundness*—The maximum out-of-roundness requirements, shown in Table 1 for tubing, apply to the average measured diameter after rounding with a rounding tool recommended by the manufacturer.

6.2.2 *Wall Thickness*—Table 2 provides for wall thickness tolerances. Calculated SDR 9 tubing wall thickness that fall below 0.070 in. (1.78 mm) shall be arbitrarily increased to that value except for sizes 1/4 in. and smaller.

6.2.3 *Fittings (Basic Dimensions)*—Fittings shall be compatible with tubing made to the requirements of Table 1 and Table 2. Fittings shall be made from materials that are generally regarded as corrosion resistant.

6.3 *Hydrostatic Burst:*

6.3.1 Tubing and fittings (tested as assemblies) shall meet the minimum hydrostatic burst requirements shown in Table 3 when tested in accordance with 7.6.

6.3.2 Fittings assembled using the manufacturer's instructions shall meet the minimum hydrostatic burst requirement shown in Table 3 when tested in accordance with 7.6.

6.4 *Hydrostatic Sustained Pressure Strength*—Tubing and fittings (tested as assemblies) shall meet the minimum hydrostatic sustained pressure strength requirements shown in Table 4 when tested in accordance with 7.4.

6.5 *Thermocycling*—Fittings, assembled using the manufacturer's instructions, shall not separate or leak when thermocycled 1000 times between the temperatures of 60°F (16°C) and 180°F (82°C) when tested in accordance with 7.5.

6.6 *Bent Tube Hydrostatic Sustained Pressure Strength:*



TABLE 1 Outside Diameters and Tolerances for PEX Tubing

Nominal Tubing Size		Average Outside Diameter		Tolerances for Average Diameter		Out of Roundness ^A	
in.	mm	in.	mm	in.	mm	in.	mm
1/8	3	0.250	6.35	±0.003	±0.08	0.008	0.20
1/4	7	0.375	9.52	±0.003	±0.08	0.008	0.20
3/8	10	0.500	12.70	±0.003	±0.08	0.012	0.32
1/2	13	0.625	15.88	±0.004	±0.10	0.016	0.40
5/8	16	0.750	19.05	±0.004	±0.10	0.016	0.40
3/4	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
1 1/4	32	1.375	34.92	±0.005	±0.12	0.020	0.48
1 1/2	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
2 1/2	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
3 1/2	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
4 1/2	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 2 Wall Thickness and Tolerances for PEX SDR 9 Plastic Tubing

Nominal Tubing		Minimum Wall Thickness		Tolerance		Average Wall Thickness, min	
in.	mm	in.	mm	in.	mm	in.	mm
1/8	3	0.047 ^A	1.19 ^A	+0.007	+0.18	0.049	1.24
1/4	7	0.062 ^A	1.57 ^A	+0.010	+0.25	0.064	1.63
5/16	8	0.064	1.63	+0.010	+0.25		
3/8	10	0.070 ^A	1.78 ^A	+0.010	+0.25	0.072	1.83
1/2	13	0.070 ^A	1.78 ^A	+0.010	+0.25	0.072	1.83
5/8	16	0.083	2.12	+0.010	+0.25	0.085	2.16
3/4	19	0.097	2.47	+0.010	+0.25	0.099	2.51
1	25	0.125	3.18	+0.013	+0.33	0.127	3.23
1 1/4	32	0.153	3.88	+0.015	+0.38	0.155	3.94
1 1/2	38	0.181	4.59	+0.019	+0.48	0.183	4.65
2	51	0.236	6.00	+0.024	+0.61	0.238	6.05
2 1/2	64	0.292	7.41	+0.030	+0.76		
3	76	0.347	8.82	+0.033	+0.84		
3 1/2	89	0.403	10.23	+0.035	+0.89		
4	102	0.458	11.64	+0.040	+1.02		
4 1/2	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 For tubing sizes of 1/2 in. and below, wall thickness minimums are not functions of SDR.

TABLE 3 Minimum Hydrostatic Burst Strength Requirements for PEX Tubing and Fittings

Nominal Tubing Size		Minimum Burst Pressures at Different Temperatures			
in.	mm	psi ^A at 73.4°F	(MPa) at (23°C)	psi ^A at 180°F	(MPa) at (82.2°C)
1/8	3	870	(6.00)	390	(2.69)
1/4	7	752	(5.19)	336	(2.32)
3/8	10	620	(4.27)	275	(1.90)
1/2	13	480	(3.31)	215	(1.48)
5/8 and larger	16 and larger	475	(3.27)	210	(1.45)

^A The fiber stress used to derive this test pressure is:
 at 73.4°F (23.0°C) 1900 psi (13.10 MPa).
 at 180°F (82.2°C) 850 psi (5.86 MPa).

6.6.1 *General*—PEX tubing can be installed bent by using either of two techniques described in X2.3.5 and X2.3.6 provided that 6.6.2 and 6.6.3 requirements are met.

6.6.2 *Hot-bent tubing*, with a radius of 2.5 times the outside diameter and consisting of a continuous bend length inducing

TABLE 4 Minimum Hydrostatic Sustained Pressure Requirements for PEX SDR 9 Tubing and Fitting Assemblies^{A,B}

Nominal Tubing Size		Pressure Required for Test, psi (MPa) ^A	
in.	mm	180°F (82.2°C)	
1/8	3	355	(2.45)
1/4	7	305	(2.10)
3/8	10	250	(1.72)
1/2	13	195	(1.34)
5/8 and larger	16 and larger	190	(1.31)

^A The fiber stress used to derive this test pressure is: 770 psi (5.31 MPa) at 180°F (82.2°C).

^B Test duration is 1000 h.

not less than 90° angle, shall meet the minimum hydrostatic sustained pressure strength requirements shown in Table 4 when tested in accordance with 7.4. The bend length and bend angle is kept throughout the testing period by rigid supports immediately outside the bend.

6.6.3 *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 shown in Table 4 when tested in accordance with 7.4. The bend length and bend angle is kept throughout the testing period by rigid secures immediately outside the bend.

6.7 Excessive Temperature—Pressure Capability:

6.7.1 *General*—In the event of a water heating system malfunction, PEX tubing 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.

6.7.2 *Excessive Temperature Hydrostatic Sustained Pressure*—Tubing and fittings, when tested as assemblies, shall not fail as defined in Test Method D 1598 in less than 30 days (720 h) when tested in accordance with 7.7.

NOTE 3—Test applicable to assemblies and bends (6.3, 6.4, 6.5, 6.6, and 6.7) are intended to be performance qualification tests and not tests required of each fitting.

7. Test Methods

7.1 *Conditioning*—The test specimens should be conditioned at 70 to 77°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Practice D 618, for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct the tests in the standard laboratory atmosphere of 70 to 77°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

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 D 1898). In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

7.4 *Hydrostatic Sustained Pressure*— Determine in accordance with Test Method D 1598, except for the following:

7.4.1 Assemble test sections using the manufacturer's instructions.

7.4.2 Test temperature shall be 180 ± 4°F (82 ± 2°C).

7.4.3 The external test environment shall be air or water.

7.4.4 Fill the specimens with water at a temperature of at least 120°F (50°C).

7.5 *Thermocycling*:

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

7.5.2 *Apparatus*—A nitrogen or air source capable of maintaining a nominal internal pressure of 100 ± 10 psi (0.69 ± 0.069 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 specimens 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 4—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.

7.5.3 *Sampling and Specimen Preparation*— Select at random six specimens of the type and size PEX tubing and compression-type fitting to be tested. Assemble the fittings with suitable lengths of tubing meeting the requirements of this specification and attach to a common manifold. Assemble strictly in accordance with the instructions of the fitting manufacturer. 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.

7.5.4 *Procedure*—Pressurize the specimen assembly with nitrogen or air to 100 ± 10 psi (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 ± 10 psi (0.69 ± 0.069 MPa), alternately between 60 ± 4°F (16 ± 2°C) and 180 ± 4°F (82 ± 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 ± 4°F (16 ± 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.

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

7.6 *Hydrostatic Burst Strength*—Determine the minimum hydrostatic strength for tubing and fitting assemblies at both 73°F (23°C) and 180°F (82°C) in accordance with Test Method D 1599, except as herein specified.

7.6.1 *Assembly*—Assemble the tubing and fittings using the manufacturer's recommended procedure.

7.6.2 *Procedure*—Test a single specimen assembly, containing at least six joints prepared from PEX tubing and fittings, meeting the requirements of this specification. After assembly, in accordance with 7.6.1, attach end closures, fill the specimen assembly with water, and condition in water at the test temperature for 2 h min (or in air for 4 h min). In the case of testing at 180°F (82°C), the sample should be filled with water of at least 120°F (50°C) temperature prior to conditioning.

7.6.2.1 Increase the internal pressure at a constant rate so as to reach the maximum burst requirement in 60 to 70 s. Leakage or separation at any of the fittings tested, at less than the minimum hydrostatic burst requirements for either temperature specified in Table 3, shall constitute failure in this test.

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

7.7.1 *Hydrostatic Sustained Pressure*— Determine in accordance with Test Method D 1598, except for the following requirements:

7.7.1.1 Select six test specimens at random.

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

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

7.7.1.4 The external test environment shall be air.

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

7.7.1.6 Pressurize test specimens to the required pressure and maintain for 30 days (720 h). The pressure for PEX SDR 9 tubing shall be 150 psi (1034 kPa). The fiber stress used to derive this test pressure is 595 psi (4.1 MPa).

8. Retest and Rejection

8.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered,