



Standard Specification for Crosslinked Polyethylene (PEX) Tubing¹

This standard is issued under the fixed designation F876; 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 crosslinked polyethylene (PEX) tubing that incorporates an optional polymeric inner, middle or outer layer and that is outside diameter controlled, made in nominal SDR9 tubing dimension ratios except where noted, and pressure rated for water at three temperatures (see [Appendix X1](#)). Included are requirements and test methods for material, workmanship, dimensions, burst pressure, hydrostatic sustained pressure, excessive temperature and pressure, environmental stress cracking, stabilizer functionality, bent-tube hydrostatic pressure, oxidative stability in potable chlorinated water, and degree of crosslinking. Requirements for tubing markings are also given. The components covered by this specification are intended for use in, but not limited to, residential and commercial, hot- and cold-potable water distribution systems, reclaimed water, fire protection, municipal water service lines, radiant heating and cooling systems, hydronic distribution systems, snow and ice melting systems, geothermal ground loops, district heating, turf conditioning, compressed air distribution and building services pipe, provided that the PEX tubing covered herein complies with applicable code requirements.

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: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
- D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
- D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
- D1600 Terminology for Abbreviated Terms Relating to Plastics
- D1898 Practice for Sampling of Plastics (Withdrawn 1998)³
- D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
- 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
- D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

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

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

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

F412 Terminology Relating to Plastic Piping Systems

F1281 Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe

F2023 Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water

F2657 Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing

2.2 *ANSI Standard:*

B36.10 Standards Dimensions of Steel Pipe (IPS)⁴

2.3 *Federal Standard:*

FED-STD-123 Marking for Shipment (Civil Agencies)⁵

2.4 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage⁵

2.5 *NSF Standard:*

NSF/ANSI 14 for Plastic Piping Components and Related Materials⁶

2.6 *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 13760 Plastics pipes for the conveyance of fluids under pressure -- Miner's rule -- Calculation method for cumulative damage

ISO R 161-1690 Pipes of Plastic Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part 1, Metric Series

2.7 *PPI Standard:*⁷

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 *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. 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 B36.10.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *crosslinked polyethylene*—a polyethylene material ~~which~~that has undergone a change in molecular structure ~~using~~a chemical or a physical process ~~whereby~~through processing whereby a majority of the polymer chains are chemically linked.

3.2.2 *hydrostatic design stress (HDS)*—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.

$$HDS = HDB \times DF \\ = HDB \times 0.50 \text{ (for this standard)}$$

3.2.3 *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.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁵ DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 <http://quicksearch.dla.mil/>

⁶ Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, <http://www.nsf.org>.

⁷ Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825 Irving TX, 75062. <http://www.plasticpipe.org>

3.2.3.1 *Discussion*—

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

3.2.4 *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.

TABLE 2-1 Thermoplastic Tubing Material Designation Code Cells for SDR9 PEX

Property	Standard	0	1	2	3	4	5	6	7	8	9
Chlorine Resistance	F2023	Not tested or rated	75 % at 73°F and 25 % at 140°F	Reserved	50 % at 73°F and 50 % at 140°F	Reserved	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	...

Thermoplastic Tubing Material Designation Code—For example ASTM F876 PEX tubing marked with the material designation code PEX 1106 is a PEX tubing meeting the chlorine resistance requirement for 25% of the time at 140°F and 75% of the time at 73°F having a Minimum UV resistance of 1 month and having an HDS for water at 73°F of 630psi (HDB of 1250 psi).

3.2.5 relation between dimensions, hydrostatic design stress, and pressure rating—the following expression, commonly known as the ISO equation,⁸ is used in this specification to relate dimensions, hydrostatic design stress, and pressure rating:

$$2S/P = (D_o/t) - 1 \tag{1}$$

or

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

where:

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

3.2.6 standard dimension ratio (SDR)—the ratio of outside diameter to wall thickness. For PEX tubing, it is calculated by dividing the average outside diameter of the tubing in inches or in millimetres by the minimum wall thickness in inches or millimetres. If the wall thickness calculated by this formula is less than 0.070 in. (1.78 mm) it shall be arbitrarily increased to 0.070 in. except for sizes 5/16 in. and smaller, as specified in Table 43. The SDR values shall be rounded to the nearest 0.5.

3.2.7 standard thermoplastic tubing materials 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 numerals — two to describe the short-term properties, in accordance with applicable ASTM standards and as shown in the ASTM standard being referenced, and two to designate the hydrostatic design stress when tested in water at 73°F (23°C) in units of 100 psi, with any decimal figures dropped. See Table 21. See Fig. 1.

⁸ ISO R161-1690.

3.2.7.1 Discussion—

- The first digit is for chlorine resistance tested in accordance with Test Method F2023.
- (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 6.106.9 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.

TABLE 4 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
5/16	8		0.430	10.92	±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

TABLE 2 Outside Diameters and Tolerances for SDR9 PEX Tubing

Nominal Tubing Size	Average Outside Diameter		Tolerances for Average Diameter		Out-of-Roundness ^A	
	in.	(mm)	in.	(mm)	in.	(mm)
1/8	0.250	(6.35)	±0.003	(±0.08)	0.008	(0.20)
1/4	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)
3/8	0.500	(12.70)	±0.003	(±0.08)	0.012	(0.32)
1/2	0.625	(15.88)	±0.004	(±0.10)	0.016	(0.40)
5/8	0.750	(19.05)	±0.004	(±0.10)	0.016	(0.40)
3/4	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)
1 1/4	1.375	(34.92)	±0.005	(±0.12)	0.020	(0.48)
1 1/2	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)
2 1/2	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)
3 1/2	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)
4 1/2	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.

(4) A digit “3” indicates that the PEX tubing has been tested and meets the requirement of 6.106.9 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 6.106.9 for minimum chlorine resistance at end use conditions of 100% of the time at 140°F

TABLE 4 Wall Thickness and Tolerances for Nominal PEX-SDR-9 Plastic Tubing^A

Nominal Tubing	Minimum Wall Thickness		Tolerance		mm	Nominal Tubing		Minimum Wall Thickness		Tolerance	
	in.	mm	in.	mm		in.	mm	in.	mm		
1/4	3	0.047 ^B	1.19 ^B	+0.007	+0.18	1 1/2	38	0.181	4.59	+0.019	+0.48
						2	51	0.236	6.00	+0.024	+0.61
						2 1/2	64	0.292	7.41	+0.030	+0.76
1/2	7	0.062 ^B	1.57 ^B	+0.010	+0.25	3	76	0.347	8.82	+0.033	+0.84
						3 1/2	89	0.403	10.23	+0.035	+0.89
5/8	10	0.070 ^B	1.78 ^B	+0.010	+0.25	4	102	0.458	11.64	+0.040	+1.02
						4 1/2	114	0.514	13.05	+0.045	+1.14
3/4	13	0.083	2.12	+0.010	+0.25						
1	16	0.097	2.47	+0.010	+0.25						
1 1/4	19	0.125	3.18	+0.013	+0.33						
1 1/2	25	0.153	3.88	+0.015	+0.38						

3.2.7.2 Discussion—

Nominal Tubing	Minimum Wall Thickness		Tolerance		
	in.	mm	in.	mm	in.
5	1.27	0.569	14.46	+0.050	+1.27
6	1.52	0.681	17.29	+0.060	+1.52

TABLE 3 Wall Thickness and Tolerances for SDR9 PEX Tubing^A

Nominal Tubing Size	Minimum Wall Thickness		Tolerance	
	in.	(mm)	in.	mm
1/8	0.047 ^B	(1.19) ^B	+0.007	(+0.18)
1/4	0.062 ^B	(1.57) ^B	+0.010	(+0.25)
5/16	0.064 ^B	(1.63) ^B	+0.010	(+0.25)
3/8	0.070 ^B	(1.78) ^B	+0.010	(+0.25)
1/2	0.070 ^B	(1.78) ^B	+0.010	(+0.25)
5/8	0.083	(2.12)	+0.010	(+0.25)
3/4	0.097	(2.47)	+0.010	(+0.25)
1	0.125	(3.18)	+0.013	(+0.33)
1 1/4	0.153	(3.88)	+0.015	(+0.38)
1 1/2	0.181	(4.59)	+0.019	(+0.48)
2	0.236	(6.00)	+0.024	(+0.61)
2 1/2	0.292	(7.41)	+0.030	(+0.76)
3	0.347	(8.82)	+0.033	(+0.84)
3 1/2	0.403	(10.23)	+0.035	(+0.89)
4	0.458	(11.64)	+0.040	(+1.02)
4 1/2	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 1/2-in. and below, wall thickness minimums are not functions of SDR.

The second digit is for demonstrated UV resistance of PEX material when tested in accordance with Test Method F2657. For PEX tubing with the first digit of the material designation code equal to 1, 3, or 5 the second digit shall be one of the classification digits listed in Table 21 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%. For PEX tubing with the first digit of the material designation code equal to 0, the second digit shall be one of the classification digits from Table 21 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, or alternatively using the criteria for potable water piping found in the preceding sentence of this clause.

3.2.7.3 Discussion—

PEX tubing is not designed for outdoor use. Data from short-term exposure testing in accordance with this test method can be used to judge the relative performance of PEX tubing stored outdoors for short periods of time prior to installation completely shielded from sunlight.

3.2.7.4 Discussion—

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

(1) 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.

(2) 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.

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

TABLE 3 Hydrostatic Design Stresses and Pressure Ratings for PEX-SDR 9 Tubing for Water at Different Temperatures

Rated Temperature		Hydrostatic Design Stress		Pressure Rating for Water	
°F	°C	psi	(MPa)	psi	(MPa)
73.4	23	630	(4.34)	160	(1.10)
180	82.2	400	(2.76)	100	(0.69)
200	93.3	315	(2.17)	80	(0.55)

TABLE 4 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)
<u>73</u>	<u>23</u>	<u>630</u>	<u>(4.34)</u>	<u>160</u>	<u>(1.10)</u>
<u>180</u>	<u>82</u>	<u>400</u>	<u>(2.76)</u>	<u>100</u>	<u>(0.69)</u>
<u>200</u>	<u>93</u>	<u>315</u>	<u>(2.17)</u>	<u>80</u>	<u>(0.55)</u>

4. Tubing Classification

4.1 *General*—This specification covers one PEX tubing material in one standard dimension ratio and having pressure ratings for water of three temperatures. The pressure ratings decrease as the temperature is increased.

4.2 *Standard Thermoplastic Pipe Dimension Ratio (SDR)*—This specification covers PEX tubing in one standard dimension ratio (SDR 9) for nominal diameters $\frac{5}{8}$ in. and larger, and with a specified wall thickness for smaller diameters. The pressure ratings are uniform for all nominal tubing sizes.

5. Materials

5.1 *General*—Crosslinked polyethylene tubing, meeting the requirements of this specification, are 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.

NOTE 1—PEX tubing intended for use in the transport of potable water should be evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation should be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in NSF/ANSI 14. The seal or mark of the laboratory making the evaluation should be included on the tubing.

5.2 *Basic Materials*—PEX tubing 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 stress ratings equal to or better than those shown in [Table 3](#), when determined in accordance with procedures no less restrictive than those of PPI TR-3. Tubing incorporating an optional layer shall also meet the requirement of PPI ~~TR-3~~TR-3.1. See [Appendix X1](#) for additional information on PPI hydrostatic stress ratings.

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.

5.3 *Tubing Material Designation*—The tubing meeting the requirements of this specification shall be designated PEX.

6. Requirements

6.1 *Workmanship*—The tubing shall be ~~homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe~~uniform in appearance and consistent throughout. The walls shall be free of cracks, holes, blisters, voids, foreign inclusion, or other defects that are visible to the naked eye and that affect the wall integrity. The tubing 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 4](#) for tubing, apply to the average, measured diameter. Tubing shall be measured prior to coiling.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameters*—The outside diameters and tolerances of the tubing including the layers shall be as shown in [Table 4](#), when measured in accordance with [7.4](#) and [7.4.1](#).

6.2.1.1 *Layer*—Tubing that incorporates an inner, middle or outer layer have to meet the minimum wall thickness and tolerances requirements as specified in [Table 4](#). In addition, the layer shall not result in the reduction of the total PEX material below that