



Designation: **F876–23** F876 – 23a

An American National Standard

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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

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, UV resistance, 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, building supply 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 either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined. The values given in parentheses are mathematical conversions that may not be exact equivalents to either SI units or inch-pound units and that are provided for information only.

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.*

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

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
- F412 Terminology Relating to Plastic Piping Systems
- 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
- 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
- F3203 Test Method for Determination of Gel Content of Crosslinked Polyethylene (PEX) Pipes and 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
- NSF/ANSI/CAN 61 Drinking Water System Components – Health Effects

2.6 *ISO Standards:*⁷

- 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 15875 Plastics piping systems for hot and cold water installations -- Crosslinked polyethylene (PE-X) -- Part 1: General
- 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:*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 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology

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.

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

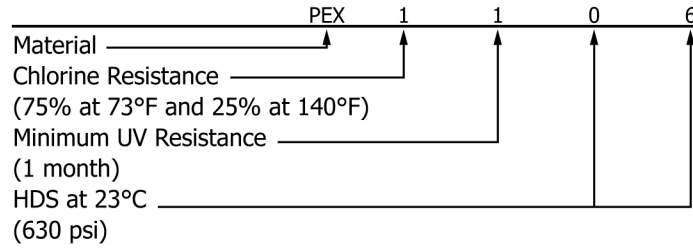
⁵ DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 <http://quicksearch.dla.mil/>

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

⁷ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

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

TABLE 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 630 psi (HDB of 1250 psi).

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 that has undergone a change in molecular structure 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.

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.

3.2.5 *relation between dimensions, hydrostatic design stress, and pressure rating*—the following expression, commonly known as the ISO equation,⁹ is used in this specification to relate dimensions, hydrostatic design stress, and pressure rating:

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

or

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

⁹ ISO R161-1690.

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.

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 and below, wall thickness minimums are not functions of SDR.

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 3**. The SDR values shall be rounded to the nearest 0.5.

3.2.7 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 numerals — two to describe the short-term properties, in accordance with 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 1**.

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 **6.9** 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.

(4) A digit “3” indicates that the PEX tubing has been tested and meets the requirement of **6.9** 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 **6.9** for minimum chlorine resistance at end use conditions of 100% of the time at 140°F

3.2.7.2 Discussion—

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 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 %. 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 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, 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 2005.¹⁰

(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.

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 material in tubing form, 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 hydrostatic strength.

5.2 *Basic Materials*—PEX tubing 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

¹⁰ PPI Technical literature, Final Report – Proposal for the Evaluation of the Chlorine Resistance of UV Exposed PEX Pipe.

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) |
| 73 | 23 | 630 | (4.34) | 160 | (1.10) |
| 180 | 82 | 400 | (2.76) | 100 | (0.69) |
| 200 | 93 | 315 | (2.17) | 80 | (0.55) |

the process for crosslinking shall result in a product with long term hydrostatic stress ratings equal to or better than those shown in [Table 4](#), 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. See [Appendix X1](#) for additional information on PPI hydrostatic stress ratings.

NOTE 1—Tubing produced by crosslinking by peroxides, 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 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 *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 2](#), 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 3](#). In addition, the layer shall not result in the reduction of the total PEX material below that specified in [Table 3](#). In the case of tubing with a middle layer, the total base PEX material wall thickness shall be the sum of the inner and outer base PEX material wall thicknesses.

6.2.2 *Wall Thickness*—The wall thickness and tolerances shall be as shown in [Table 3](#), when measured in accordance with [7.4](#) and [7.4.2](#).

NOTE 2—Tubing diameters less than 5/8 in. diameter have minimum wall thicknesses based on both hydrostatic and mechanical strength.

6.2.3 *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.

6.2.4 *Coil diameters*—PEX tubing may be supplied in either straight lengths or coils with a minimum coiling diameter based on a tubing bend radius of 10 times the outside diameter.

6.3 *Density*—When determined in accordance with [7.5](#), the crosslinked polyethylene tubing shall have a minimum density of 0.926 g/cm³.

6.4 *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 5](#) or [Table 6](#) when tested in accordance with [7.6](#).

6.5 *Hydrostatic Burst Pressure*—The minimum burst pressure for PEX plastic tubing shall be as shown in [Table 7](#), when determined in accordance with [7.7](#).