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# Standard Specification for Metric and Inch-sized Crosslinked Polyethylene (PEX) Pipe[1]

This standard is issued under the fixed designation F2788/F2788M; 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) pipe that is outside diameter controlled in metric pipe sizes 16 mm to 100 mm and inch pipe sizes 3 in. to 54 in., made in nominal pipe dimension ratios, 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-pressure, environmental stress cracking, stabilizer functionality, bent-pipe hydrostatic pressure, oxidative stability in potable chlorinated water, and degree of crosslinking. Requirements for pipe markings are also given. The pipe covered by this specification is intended for buried pressure piping applications (such as, industrial and general-purpose pipelines, potable water pipelines, fire – extinguishing pipelines). This specification also includes carbon black requirements for PEX pipe used for aboveground pressure piping applications.

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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Metric sized (SI units) pipe should only be joined with corresponding metric-sized fittings and inch-sized pipe should only be joined with corresponding inch-sized fittings. Inch sized fittings should not be used for metric sized pipe, and metric sized fittings should not be used for inch-sized pipe.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 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



[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**

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

2.2 *ANSI Standard:*[4]
B36.10 Standards Dimensions of Steel Pipe (IPS)
2.3 *Federal Standard:*[5]
FED-STD-123 Marking for Shipment (Civil Agencies)
2.4 *Military Standard:*[5]
MIL-STD-129 Marking for Shipment and Storage
2.5 *NSF Standard:*[6]
NSF/ANSI 14 for Plastic Piping Components and Related Materials
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 4427 Plastic piping systems - Polyethylene (PE) pipes and fittings for water supply
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 Standards:*[8]
PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe
PPI TR-4 PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

## 3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for crosslinked polyethylene is PEX. Plastic pipe denotes a particular diameter schedule of plastic pipe in which outside diameter of the pipe conforms with ISO 4427.

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *crosslinked polyethylene plastics*—plastics prepared by crosslinking (curing) polyethylene compounds.

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 pipe 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.

$$HDS = HDB \times DF \tag{1}$$
$$= HDB \times 0.50 \ (\textit{for this standard})$$



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] ~~Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.~~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), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.
[8] Available from 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 pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe 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:

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

[9] ISO R161–1690.

$S$ = 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) or dimension ratio (DR)

3.2.6 *standard dimension ratio (SDR)/dimension ratio (DR)*—the ratio of outside diameter to wall thickness. For PEX-pipe, it is calculated by dividing the average outside diameter of the pipe by the minimum wall thickness. If the calculated dimension ratio is a Preferred Number Series R 10 modified by +1 (7, 9, 11 etc.), then it is called an SDR (standard dimension ratio); for all other numbers, it is called a DR.

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

3.2.7.1 *Discussion*—

The first digit is for chlorine resistance tested in accordance with Test Method F2023.
*(1)* A digit "0" indicates that the PEX pipe either has not been tested for chlorine resistance or that the PEX pipe does not meet the minimum requirement for chlorine resistance.
*(2)* A digit "1" indicates the PEX pipe has been tested and meets the ~~F XXXX~~ FXXXX requirement 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 pipe has been tested and meets the ~~F XXXX~~ FXXXX requirement 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 pipe has been tested and meets the requirement 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 a "0". This digit is reserved for a currently unspecified PEX pipe property.

3.2.7.3 *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 pipe shall consist of the three letters "PEX" and four digits.

## 4. Pipe Classification

4.1 *General*—This specification covers one PEX pipe material having pressure ratings for water at three temperatures. The pressure ratings decrease as the temperature is increased.

4.2 *Standard Dimension Ratio (SDR)*—This specification covers PEX pipe in various standard dimension ratios and dimension ratios for nominal diameters 16 mm (½ in) and larger. The pressure ratings are uniform for all nominal pipe sizes with the same DR or SDR.

## 5. Materials

5.1 *General*—Crosslinked polyethylene pipe, 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.

**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 | 75 % at 73°F and 25 % at 140°F | Re-served | 50 % at 73°F and 50 % at 140°F | Re-served | 100 % at 140°F | ... | ... | ... | ... |
| Reserved | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| HDS for water at 73°F | ... | ... | ... | ... | ... | ... | ... | 630 | ... | 800 | ... |

NOTE 2—PEX pipe 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 pipe.

5.2 *Basic Materials*—PEX pipe 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 pipe meets the performance requirements of Section 6. For the use temperatures that the pipe 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 better than those~~design stresses and pressure ratings as shown in Table 2, when determined in accordance with procedures no less restrictive than those of PPI TR-3[9]. See Appendix X1 for additional information on PPI hydrostatic stress ratings.

NOTE 3—Pipe 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 pipe. However, each process must be established as meeting the requirements of this specification.

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

5.4 *Carbon Black*—When black PEX pipe is intended for aboveground applications, the black PEX compound shall contain 2% to 3% carbon black. When PEX pipe is intended for applications other than above ground (UV exposed), see Appendix X2 for UV labeling guidelines.

**TABLE 2 ~~Material Designation Code Cells~~PEX Pipe Pressure Ratings Based on DR/SDR and Temperature**

| DR/SDR | Rated Temperature | | Hydrostatic Design Stress | | Pressure Rating for Water | |
|---|---|---|---|---|---|---|
| | °F | °C | psi | MPa | Psig | MPa |
| ~~DR 6~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~210~~ | ~~1.45~~ |
| DR 6 | 73.4 | (23) | 630 | (4.34) | 250 | (1.72) |
| | 73.4 | (23) | 800 | (5.51) | 320 | (2.21) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~160~~ | ~~1.10~~ |
| | 180 | (82.2) | 400 | (2.76) | 160 | (1.10) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~125~~ | ~~0.86~~ |
| | 200 | (93.3) | 315 | (2.17) | 125 | (0.86) |
| ~~DR 7.4~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~200~~ | ~~1.60~~ |
| DR 7.4 | 73.4 | (23) | 630 | (4.34) | 200 | (1.38) |
| | 73.4 | (23) | 800 | (5.51) | 250 | (1.72) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~125~~ | ~~0.86~~ |
| | 180 | (82.2) | 400 | (2.76) | 125 | (0.86) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~100~~ | ~~0.69~~ |
| | 200 | (93.3) | 315 | (2.17) | 100 | (0.69) |
| ~~SDR 9~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~160~~ | ~~1.10~~ |
| SDR 9 | 73.4 | (23) | 630 | (4.34) | 160 | (1.10) |
| | 73.4 | (23) | 800 | (5.51) | 200 | (1.38) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~100~~ | ~~0.69~~ |
| | 180 | (82.2) | 400 | (2.76) | 100 | (0.69) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~80~~ | ~~0.55~~ |
| | 200 | (93.3) | 315 | (2.17) | 80 | (0.55) |
| ~~SDR 11~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~125~~ | ~~0.86~~ |
| SDR 11 | 73.4 | (23) | 630 | (4.34) | 125 | (0.86) |
| | 73.4 | (23) | 800 | (5.51) | 160 | (1.10) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~80~~ | ~~0.55~~ |
| | 180 | (82.2) | 400 | (2.76) | 80 | (0.55) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~60~~ | ~~0.41~~ |
| | 200 | (93.3) | 315 | (2.17) | 60 | (0.41) |
| ~~DR 13.6~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~100~~ | ~~0.69~~ |
| DR 13.6 | 73.4 | (23) | 630 | (4.34) | 100 | (0.69) |
| | 73.4 | (23) | 800 | (5.51) | 125 | (0.86) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~60~~ | ~~0.41~~ |
| | 180 | (82.2) | 400 | (2.76) | 60 | (0.41) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~50~~ | ~~0.35~~ |
| | 200 | (93.3) | 315 | (2.17) | 50 | (0.35) |
| ~~DR 16.2~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~41~~ | ~~0.28~~ |
| DR 16.2 | 73.4 | (23) | 630 | (4.34) | 41 | (0.28) |
| | 73.4 | (23) | 800 | (5.51) | 105 | (0.72) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~26~~ | ~~0.18~~ |
| | 180 | (82.2) | 400 | (2.76) | 26 | (0.18) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~21~~ | ~~0.14~~ |
| | 200 | (93.3) | 315 | (2.17) | 21 | (0.14) |
| ~~SDR 17~~ | ~~73.4~~ | ~~23~~ | ~~630~~ | ~~4.34~~ | ~~80~~ | ~~0.55~~ |
| SDR 17 | 73.4 | (23) | 630 | (4.34) | 80 | (0.55) |
| | 73.4 | (23) | 800 | (551) | 100 | (0.69) |
| | ~~180~~ | ~~82.2~~ | ~~400~~ | ~~2.76~~ | ~~50~~ | ~~0.35~~ |
| | 180 | (82.2) | 400 | (2.76) | 50 | (0.35) |
| | ~~200~~ | ~~93.3~~ | ~~315~~ | ~~2.17~~ | ~~40~~ | ~~0.28~~ |
| | 200 | (93.3 | 315 | (2.17) | 40 | (0.28) |

NOTE 4—Plastics Pipe Institute literature states, "It has been demonstrated that a minimum of 2% well-dispersed very fine particle carbon black is sufficient protection for continuous outdoor service".

## 6. Requirements

6.1 *Workmanship*—The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.2 *Out-of Roundness*—The maximum out-of roundness requirements, shown in Table 3 for pipe, apply to the average, measured diameter after rounding with a rounding tool recommended by the manufacturer.

6.3 *Dimensions and Tolerances:*

6.3.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 3 for metric sizes or Table 4 for inch sizes, when measured in accordance with 7.4 and 7.4.1.

6.3.2 *Wall Thickness*—The wall thickness shall be as shown in Table 5 for metric sizes and Table 6 for inch sizes, when measured in accordance with 7.4 and 7.4.2. The tolerance for all wall thicknesses is plus 12%.

NOTE 5—Pipe diameters less than 25 mm (1 in.) diameter have minimum wall thicknesses based on both hydrostatic and mechanical strength.

6.4 *Density*—When determined in accordance with 7.5, the crosslinked polyethylene pipe material shall have a minimum density of 0.926 $Mg/m^3$.

6.5 *Hydrostatic Sustained Pressure Strength*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598, at the test pressures shown in Table 7 when tested in accordance with 7.6. The test pressure is based on the formula:

*P (test pressure) = 2 (fiber stress) / [(average OD/minimum wall) - 1]*

For most of the pipe sizes, average OD/minimum wall is the DR or SDR. For the smaller pipe sizes, the calculated value is slightly lower than the DR or SDR value, and this will result in a slightly higher test pressure, as seen in Table 7. The fiber stress values are provided in Table 7 for the three temperatures.

6.6 *Hydrostatic Burst Pressure*—The minimum burst pressure for PEX plastic pipe shall be as shown in Table 8, when determined in accordance with 7.7. The minimum burst pressure is based on the formula:

*P (burst pressure) = 2 (fiber stress) / [(average OD/minimum wall) - 1].*

For most of the pipe sizes, average OD/minimum wall is the DR or SDR. For the smaller pipe sizes, the calculated value is slightly lower than the DR or SDR value, and this will result in a slightly higher burst pressure, as seen in Table 1. The fiber stress values are provided in Table 1 for the three temperatures.

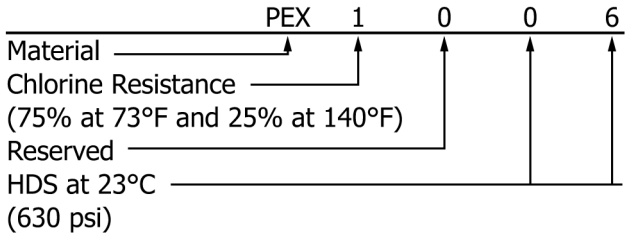
6.7 *Environmental Stress Cracking*—There shall be no loss of pressure in the pipe, when tested in accordance with 7.8.

6.8 *Degree of Crosslinking*—When tested in accordance with 7.9, the degree of crosslinking for PEX pipe material shall be 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 Azo compounds, 65 % by electron beam, or 65 % by silane compounds.

NOTE 6—Techniques as found in Test Methods D2765.

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

NOTE 7—For example PEX pipe marked with the material designation code PEX 1006 is a PEX pipe meeting the chlorine resistance requirement for 25% of the time at 140°F and 75% of the time at 73°F and having an HDS for water at 73°F of 630psi (HDB of 1250 psi) as follows:




6.10 *Oxidative Stability in Potable Chlorinated Water Applications*—PEX pipe intended for use in the transport of potable water shall have a minimum extrapolated time-to-time failure of 50 years when tested and evaluated in accordance with 7.11.

6.11 *Bent Pipe Hydrostatic Sustained Pressure Strength:*

6.11.1 *General*—PEX pipe, up to and including 25 mm (1 in.) nominal diameter, shall meet 6.11.2 and 6.11.3.

NOTE 8—PEX pipe, larger than 25 mm (1 in.) 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 6.11.2 and 6.11.3 are intended to evaluate PEX pipe installed in tight bend applications in accordance with the procedures in X3.2.4 and X3.2.5. This application applies to pipe up to and including 1 in nominal diameter only.