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.

Designation: F2788/F2788M – 21

An American National Standard

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 of DN 16 to DN 1000 (approximate outside diameters of 16 mm to 1005 mm) and inch pipe sizes NPS 3 to NPS 54 (approximate outside diameters of 3.5 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, degree of crosslinking, and minimum operating temperature. Requirements for pipe markings are also specified. The pipe covered by this specification is intended for pressure applications, such as, industrial and general-purpose pipelines, potable water pipelines, and fire–extinguishing pipelines

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.

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
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
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
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
F1055 Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
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

[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.

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

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F2829/F2829M Specification for Metric- and Inch-Sized Fittings for Crosslinked Polyethylene (PEX) Pipe
F3373 Specification for Polyethylene (PE) Electrofusion Fittings for Outside Diameter Controlled Crosslinked Polyethylene (PEX) Pipe
2.2 *ANSI Standard:*[3]
B36.10 Standards Dimensions of Steel Pipe (IPS)
2.3 *Federal Standard:*[4]
FED-STD-123 Marking for Shipment (Civil Agencies)
2.4 *Military Standard:*[4]
MIL-STD-129 Marking for Shipment and Storage
2.5 *NSF Standard:*[5]
NSF/ANSI Standard 14 Plastic Piping System Components and Related Materials
NSF/ANSI Standard 61 Drinking Water System Components – Health Effects
2.6 *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 4427 Plastic piping systems - Polyethylene (PE) pipes and fittings for water supply
ISO 13477 Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4 test)
ISO 13760 Plastics pipes for the conveyance of fluids under pressure — Miner's rule ~ Calculation method for cumulative damage
ISO 14531-1 Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications — Part 1: Pipes
ISO 161-1 Thermoplastics pipes for the conveyance of fluids - Nominal outside diameters and nominal pressures - Part 1: Metric series
2.7 *PPI Standards:*[7]
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
PEX Pipe Design Manual for Water, Oil, Gas & Industrial Applications

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[4] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/
[5] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, http://www.nsf.org.
[6] 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.
[7] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.

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 *design factor (DF), n*—a number between 0 and 1 that is multiplied by the hydrostatic design basis to determine the hydrostatic design stress for water.

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) multiplied by the design factor (DF) for water. For this standard, the design factor for water 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.

3.2.3.1 *Discussion*—A listing of HDB and HDS values are contained in PPI publication PPI TR-4

3.2.4 *nominal diameter (DN), adj*—a designation for SI unit outside diameter controlled pipe sizes that generally comply with outside diameters specified in ISO 161-1.

3.2.5 *nominal pipe size (NPS), adj*—a designation for inch-pound unit outside diameter controlled pipe sizes that generally comply with outside diameters specified in ANSI B36.

3.2.6 *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.

3.2.7 *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:

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

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

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)

3.2.8 *standard pipe material designation code*—The pipe material designation code shall consist of the abbreviation for

[8] ISO 161–1.

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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.

3.2.8.1 *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 requirement of 6.10 for minimum chlorine resistance at the end use condition of 25 % of the time 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 requirement of 6.10 for minimum chlorine resistance at end use condition of 50 % of the time at 140 °F (60 °C) and 50 % of the time at 73 °F (23 °C).

(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 (60 °C) .

3.2.8.2 *Discussion*—The second digit is reserved for demonstrated UV resistance of PEX material when tested in accordance with Test Method F2657. This digit may be any value as listed for the material in PPI TR-4. Completed testing to Test Method F2657 is not a requirement of this specification.

3.2.8.3 *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 PEX pipe materials having pressure ratings for water at 73 °F (23 °C) and an elevated temperature(s). 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.

4.3 *Operating Temperature Range*—The minimum operating temperature shall be in accordance with 6.13. The maximum temperature for continuous operation shall be based on the highest temperature HDS in accordance with 5.2 and Table 2. The maximum temperature for intermittent operation shall require special design considerations and consultation with the pipe manufacturer and shall be consistent with the PPI "*PEX Pipe Design Manual for Water, Oil, Gas & Industrial Applications*."

5. Materials

5.1 *General*—Crosslinked polyethylene pipe, 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 strength tests. There is a strong correlation between nominal density and results of short-term strength tests.

NOTE 1—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 using an electron beam after extrusion, or by other means. Whatever means are used to crosslink the polyethylene and form pipe, the pipe shall meet the performance requirements of this specification. 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 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[8]. See Appendix X1 for additional information on PPI hydrostatic stress ratings.

NOTE 2—Pipe produced by crosslinking by peroxides, azo compounds, or silane compounds in extrusion, or by electron beam after extrusion have met the requirements of this specification. There are several processes for producing crosslinked polyethylene pipe. Whatever process is used, the pipe produced 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 *Color:*

5.4.1 If the color of the pipe is black, the formulation shall contain carbon black as a colorant, and the formulation shall meet the requirements of 5.5.

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 (23 °C) and 25 % at 140 °F (60 °C)	Reserved	50 % at 73 °F (23 °C) and 50 % at 140 °F (60 °C)	Reserved	100 % at 140 °F (60 °C)	...	...	...	...
Reserved for UV Weathering	...	...	...	...	...	...	...	...	...	...	...
HDS for water at 73 °F	...	...	...	...	...	...	...	630	...	800	...

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TABLE 2 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)	250	(1.72)
	73.4	(23)	800	(5.51)	320	(2.21)
	180	(82.2)	400	(2.76)	160	(1.10)
	200	(93.3)	315	(2.17)	125	(0.86)
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)
	200	(93.3)	315	(2.17)	100	(0.69)
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)
	200	(93.3)	315	(2.17)	80	(0.55)
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)
	200	(93.3)	315	(2.17)	60	(0.41)
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)	63	(0.43)
	200	(93.3)	315	(2.17)	50	(0.35)
DR 16.2	73.4	(23)	630	(4.34)	82	(0.56)
	73.4	(23)	800	(5.51)	105	(0.72)
	180	(82.2)	400	(2.76)	52	(0.36)
	200	(93.3)	315	(2.17)	41	(0.28)
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)
	200	(93.3	315	(2.17)	40	(0.28)

5.4.2 If black pipe has colored stripes, the color of the stripes shall conform to the APWA Uniform Color Code.

5.4.3 If the color of the pipe is non-black, the formulation shall contain a non-black pigment, and the formulation shall meet the requirements of 5.5. The color of the pipe shall conform to the APWA Uniform Color Code.

5.5 *UV Protection:*

5.5.1 The material formulation shall contain additives to protect the pipe from UV radiation. The pipe shall be marked with the maximum UV exposure time, based on the manufacturer's testing of UV exposed pipe in accordance with Test Method F2657, Practice D2565 or ISO 14531-1 Annex C. After PEX pipe has been weathered, it shall meet the thermal stability, 95 °C hydrostatic strength, and elongation at break requirements of ISO 14531-1 Table 8.

5.5.2 See Appendix X2 for UV labeling guidelines.

5.6 Potable Water Applications Material formulations intended for chlorinated potable water applications per 3.2.8 shall first be weathered in accordance with 5.5 using Test Method F2657, and then shall meet the requirements of 6.10.

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.

TABLE 3 Outside Diameters and Tolerances for Metric-sized PEX Pipe

DN (Nominal Diameter)	Average Outside Diameter	Tolerances for Average Diameter	Maximum Out-of-Roundness
	mm	mm	mm
16	16.15	±0.15	1.2
20	20.15	±0.15	1.2
25	25.1	±0.15	1.2
32	32.15	±0.15	1.3
40	40.20	±0.20	1.4
50	50.20	±0.20	1.4
63	63.20	±0.20	1.5
75	75.25	±0.25	1.6
90	90.30	±0.30	1.8
110	110.35	±0.35	2.2
125	125.40	±0.40	2.5
140	140.45	±0.45	2.8
160	160.50	±0.50	3.2
180	180.55	±0.55	3.6
200	200.60	±0.60	4.0
225	225.70	±0.70	4.5
250	250.75	±0.75	5.0
280	280.85	±0.85	9.8
315	315.95	±0.95	11.1
355	356.10	±1.10	12.5
400	410.20	±1.20	14.0
450	451.35	±1.35	15.6
500	501.50	±1.50	17.5
560	561.70	±1.70	19.6
630	631.90	±1.90	22.1
710	713.20	±3.20	24.9
800	813.60	±3.60	28.0
900	904.05	±4.05	31.5
1000	1004.50	±4.50	35.0

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