



Standard Specification for MRS-Rated Metric- and Inch-sized Crosslinked Polyethylene (PEX) Pressure Pipe¹

This standard is issued under the fixed designation F3288/F3288M; 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 (DN 16 to 1000) and inch pipe sizes (NPS 3 to 54), and pressure rated (see [Appendix X1](#)) using the MRS rating system. This Specification is intended for PEX pipe made by various processes, as long as the PEX pipe made by that process meets all the requirements of this Specification. Included are requirements and test methods for material, workmanship, UV protection, dimensions, hydrostatic sustained pressure, environmental stress cracking, stabilizer functionality, bent-pipe hydrostatic pressure, oxidative stability in potable chlorinated water, minimum operating temperature, degree of crosslinking, and hydrostatic burst pressure. Requirements for pipe markings are also given. The pipe covered by this specification is intended for pressure piping applications such as, industrial and general-purpose pipelines, potable water pipelines, fire – extinguishing pipelines, oil and gas producing applications to convey fluids such as oil, dry or wet gas, gas gathering, multiphase fluids, and non-potable oilfield water, and chemical pipelines. It is not intended for municipal natural gas distribution.

1.2 This specification also includes requirements for qualifying joints made using polyethylene electrofusion fittings and PEX pipe. Installation considerations are in [X3.2](#).

NOTE 1—NPS fittings should not be used for DN sized pipe, and DN sized fittings should not be used for NPS pipe.

1.3 The text of this specification references notes, footnotes, and appendixes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) should not be considered as requirements of the specification.

1.4 *Units*—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.

1.4.1 For consistency with ISO 9080, MRS values are only in MPa and degrees Centigrade for conversion to the pipe material designation code (for example PEX pipe with an MRS of 8 MPa is called a PEX 80).

1.5 *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.*

1.6 *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
- D1603 Test Method for Carbon Black Content in Olefin 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

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.

Current edition approved Aug. 1, 2020. Published August 2020. DOI: 10.1520/F3288-20

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.

- 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
- D4218** Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- D5596** Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- F412** Terminology Relating to Plastic Piping Systems
- 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
- F3373** Specification for Polyethylene (PE) Electrofusion Fittings for Outside Diameter Controlled Crosslinked Polyethylene (PEX) Pipe
- 2.2 *Federal Standard*.³
- FED-STD-123** Marking for Shipment (Civil Agencies)
- 2.3 *Military Standard*.³
- MIL-STD-129** Marking for Shipment and Storage
- 2.4 *NSF Standards*.⁴
- NSF/ANSI 14** for Plastic Piping Components and Related Materials
- NSF/ANSI 61** for Drinking Water System Components-Health Effects
- 2.5 *ISO Standards*.⁵
- ISO 1167** Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 1: General method
- ISO 3126** Plastics piping systems – Plastics components – Determination of dimensions
- ISO 9080** Plastics piping and ducting systems—Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation
- ISO 12162** Thermoplastics materials for pipes and fittings for pressure applications—Classification and designation— Overall service (design) coefficient
- 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 (PEX) pipe systems for the conveyance of

gaseous fuels — Metric series — Specifications — Part 1: Pipes

ISO 18553 Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds.

2.6 *PPI Standards*.⁶

PPI TN-17 Crosslinked Polyethylene (PEX) Tubing

PPI TR-3 HDB/HDS/PDB/SDB/MRS/CRS Policies - 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), and Categorized Required Strength (CRS) Ratings for Thermoplastic Piping Materials or Pipe

PPI TR-4 HDB/HDS/SDB/PDB/MRS/CRS

Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB), Minimum Required Strength (MRS), Categorized Required Strength (CRS) Ratings for Thermoplastic Piping Materials or Pipe

3. Terminology

3.1 *Definitions*—Unless otherwise specified, definitions, abbreviations and initials are in accordance with Terminology **F412** and Terminology **D1600**.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *minimum required strength (MRS)*—see ISO 12162 for MRS definition.

3.2.1.1 *Discussion*—MRS is determined only at 20 °C and 50 years. For a design temperature other than 20 °C or a design time other than 50 years, CRS is used in place of MRS, as discussed in 3.2.2.

3.2.2 *categorized required strength (CRS) or CRS(θ, t), n*—see ISO 12162 for CRS definition.

3.2.2.1 *Discussion*—The MRS of a compound is determined before a CRS can be determined. CRS is used for a design time other than 50 years or a design temperature other than 20 °C. An example of the use of CRS is provided in **Appendix X2**.

3.2.3 *nominal diameter, DN, adj*—a designation for SI unit outside diameter controlled pipe sizes.

3.2.4 *nominal pipe size, NPS, adj*—a designation for inch-pound unit outside diameter controlled pipe sizes.

3.2.5 *overall design coefficient (C), n*—a factor with a value greater than 1, which takes into consideration material properties (C_M) and application service conditions (C_A), as well as properties of the components of a piping system other than those represented in the lower predictive limit. Minimum overall design coefficients (C_{min}) are specified in ISO 12162 for various plastic piping materials. For PEX, C_{min} is 1.25 as specified in ISO 12162. See **Appendix X1** for further discussion on design coefficients.

³ Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, <http://quicksearch.dla.mil>.

⁴ Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48105, <http://www.nsf.org>.

⁵ Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

⁶ Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, <http://www.plasticpipe.org>.

$$C = C_M \times C_A = 1.25 \times C_A \text{ or} \quad (1)$$

$$C = 1.25 \times C_{A1} \times C_{A2} \times$$

...if there are multiple applications design coefficients

Discussion—design coefficients are sometimes referred to as reduction factors.

3.2.5.1 material design coefficient (C_M), n —factor that takes into account the properties of the plastic material. For PEX, the material coefficient (C_M) is 1.25, as specified in ISO 12162.

3.2.5.2 application design coefficient (C_A), n —a factor that takes into account various aspects of the installation or the application that the plastic pipe is used for. The application coefficient is left to the design engineer to incorporate via appropriate design codes and national regulations and should be dependent on the location of the pipeline, on the temperature, on the type of fluid being conveyed, and on the installation method.

3.2.6 design stress (σ_s), n —stress equal to the MRS or CRS divided by the overall design coefficient (C).

$$\sigma_s = (\text{MRS or CRS})/C \quad (2)$$

3.2.7 maximum operating pressure (MOP), n —the estimated maximum pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur, as shown in the following equations that are used in this specification to relate dimensions, design stress, and maximum operating pressure.

$$\text{MOP} = 2\sigma_s / [(D_o/t) - 1], \text{ or} \quad (3)$$

$$\text{MOP} = 2\sigma_s / (R-1)$$

For MOP at a temperature other than 20 °C or a time other than 50 years:

$$\text{MOP} = 2(\text{CRS}) / [(R-1)(C)], \quad (4)$$

$$\text{MOP} = 2(\text{CRS}) / [(R-1)(C_M \times C_A)] \quad (5)$$

where:

- σ_s = design stress, MPa
- MOP = maximum operating pressure, MPa
- D_o = average outside diameter, see [Table 1](#) (mm) or [Table 2](#) (in.)
- t = minimum wall thickness, see [Table 3](#) (mm) or [Table 4](#) (in.)
- R = standard dimension ratio (SDR) or dimension ratio (DR)
- MRS = Minimum Required Strength, MPa
- CRS = Categorized Required Strength, MPa
- C = Overall Design Coefficient

3.2.7.1 Discussion—MOP is sometimes referred to as PN or nominal pressure

3.2.8 material designation, n —As used in this standard, the material designation for PEX pipe shall consist of the abbreviation for the type of plastic (PEX) followed by two or three Arabic digits, which are the MRS (in MPa only) times ten, as shown in [Table 5](#).

TABLE 1 Outside Diameters and Tolerances for DN size PEX Pipe

DN Size	Minimum outside diameter (mm)	Maximum outside diameter (mm)	Maximum of absolute out-of-roundness ^A (mm)
16	16.0	16.3	1.2
20	20.0	20.3	1.2
25	25.0	25.3	1.2
32	32.0	32.3	1.3
40	40.0	40.4	1.4
50	50.0	50.4	1.4
63	63.0	63.4	1.5
75	75.0	75.5	1.6
90	90.0	90.6	1.8
110	110.0	110.7	2.2
125	125.0	125.8	2.5
140	140.0	140.9	2.8
160	160.0	161.0	3.2
180	180.0	181.1	3.6
200	200.0	201.2	4.0
225	225.0	226.4	4.5
250	250.0	251.5	5.0
280	280.0	281.7	9.8
315	315.0	316.9	11.1
355	355.0	357.2	12.5
400	400.0	402.4	14.0
450	450.0	452.7	15.6
500	500.0	503.0	17.5
560	560.0	563.4	19.6
630	630.0	633.8	22.1
710	710.0	716.4	24.9
800	800.0	817.2	28.0
900	900.0	908.1	31.5
1000	1000.0	1009.0	35.0

^A Values are consistent with ISO 14531-1.

TABLE 2 Outside Diameters and Tolerances for NPS PEX Pipe

NPS	Average Outside Diameter	Tolerances for Average Diameter ($\pm$)	Maximum of absolute out-of-roundness ^A
	in.	in.	in.
3	3.500	0.016	0.07
4	4.500	0.020	0.09
5	5.563	0.025	0.11
6	6.625	0.030	0.13
8	8.625	0.039	0.17
10	10.750	0.048	0.22
12	12.750	0.057	0.26
14	14.000	0.063	0.28
16	16.000	0.072	0.40
18	18.000	0.081	0.54
20	20.000	0.090	0.60
22	22.000	0.099	0.66
24	24.000	0.108	0.72
26	26.000	0.117	0.78
28	28.000	0.126	0.98
30	30.000	0.135	1.05
32	32.000	0.144	1.12
34	34.000	0.153	1.19
36	36.000	0.162	1.26
42	42.000	0.189	1.47
48	48.000	0.216	1.68
54	54.000	0.243	1.89

^A Values are consistent with ISO 14531-1

4. Pipe Classification

4.1 General—This specification covers two PEX pipe material designations – PEX 80 with an MRS of 8.0 MPa and



TABLE 3 Minimum Wall Thicknesses for DN size PEX Pipe

All dimensions in mm ^A							
DN Size	DR 6	DR 7.4	SDR 9	SDR 11	DR 13.6	DR 16.2	SDR 17
16	3.0	2.3	2.0	...	...	...	...
20	3.4	3.0	2.3	2.0	...	...	...
25	4.2	3.5	3.0	2.3	2.0	...	...
32	5.4	4.4	3.6	3.0	2.4	2.0	2.0
40	6.7	5.5	4.5	3.7	3.0	2.5	2.4
50	8.3	6.9	5.6	4.6	3.7	3.1	2.9
63	10.5	8.6	7.1	5.8	4.7	3.9	3.7
75	12.5	10.3	8.4	6.8	5.6	4.6	4.4
90	15.0	12.3	10.1	8.2	6.7	5.6	5.3
110	18.3	15.1	12.3	10.0	8.1	6.8	6.5
125	20.8	17.1	14.0	11.4	9.2	7.7	7.4
140	23.3	19.2	15.7	12.7	10.3	8.7	8.2
160	26.6	21.9	17.9	14.6	11.8	9.9	9.4
180	29.9	24.6	20.1	16.4	13.3	11.1	10.6
200	33.2	27.4	22.4	18.2	14.7	12.4	11.8
225	37.4	30.8	25.2	20.5	16.6	13.9	13.2
250	41.5	34.2	27.9	22.7	18.4	15.5	14.7
280	46.5	38.3	31.3	25.4	20.6	17.3	16.5
315	52.3	43.1	35.2	28.6	23.2	19.5	18.5
355	59.0	48.5	39.7	32.2	26.1	21.9	20.9
400	...	54.7	44.7	36.3	29.4	24.7	23.5
450	...	61.5	50.3	40.9	33.1	27.8	26.5
500	...	...	55.8	45.4	36.8	30.9	29.4
560	...	...	62.5	50.8	41.2	34.6	32.9
630	...	...	70.3	57.2	46.3	38.9	37.0
710	...	...	79.3	64.5	52.2	43.9	41.8
800	...	...	89.3	72.6	58.8	49.4	47.0
900	...	...	...	81.7	66.2	56.6	52.9
1000	...	...	...	90.2	72.5	61.8	58.8

^A Small pipe diameters have minimum wall thicknesses values greater than the calculated value based on DR or SDR.

TABLE 4 Minimum Wall Thicknesses for NPS PEX Pipe

All dimensions in inches ^A								
NPS	DR 7.3	DR 8.3	SDR 9	SDR 11	DR 13.5	DR 15.5	SDR 17	SDR 21
3	0.479	0.422	0.389	0.318	0.259	0.226	0.206	0.167
4	0.616	0.542	0.500	0.409	0.333	0.290	0.265	0.214
5	0.762	0.670	0.618	0.506	0.412	0.359	0.327	0.265
6	0.908	0.798	0.736	0.602	0.491	0.427	0.390	0.315
8	1.182	1.039	0.958	0.784	0.639	0.556	0.507	0.411
10	1.473	1.295	1.194	0.977	0.796	0.694	0.632	0.512
12	1.747	1.536	1.417	1.159	0.944	0.823	0.750	0.607
14	1.918	1.687	1.556	1.273	1.037	0.903	0.824	0.667
16	2.192	1.928	1.778	1.455	1.185	1.032	0.941	0.762
18	2.466	2.169	2.000	1.636	1.333	1.161	1.059	0.857
20	...	2.409	2.222	1.818	1.481	1.290	1.176	0.952
22	...	...	2.444	2.000	1.630	1.419	1.294	1.048
24	...	...	2.667	2.182	1.778	1.548	1.412	1.143
26	...	...	...	2.364	1.926	1.677	1.529	1.238
28	...	...	...	2.545	2.074	1.806	1.647	1.333
30	...	...	...	2.727	2.222	1.935	1.765	1.429
32	...	...	...	2.909	2.370	2.065	1.882	1.524
34	...	...	...	3.091	2.519	2.194	2.000	1.619
36	...	...	...	3.273	2.667	2.323	2.118	1.714
42	...	...	...	...	...	2.710	2.471	2.000
48	...	...	...	...	...	3.097	2.824	2.286
54	...	...	...	...	...	...	3.176	2.571

^A Small pipe diameters have minimum wall thicknesses values greater than the calculated value based on DR or SDR.

PEX 100 with an MRS of 10.0 MPa. The maximum operating pressure (MOP) for PEX pipe is based on the MRS or CRS and shall be determined in accordance with the equations in 3.2.7.

NOTE 2—The CRS for PEX pipe is only determined after the MRS is established.

TABLE 5 Material Designation For PEX Pipe

Material Designation	MRS (20 °C and 50 years) MPa
PEX 80	8.0
PEX 100	10.0

4.2 *Operating Temperature Range*—The determination of the minimum operating temperature shall be in accordance with 6.10. The maximum operating temperature is based on the maximum temperature at which a CRS is determined by the pipe manufacturer or is listed in PPI TR-4, but not greater than 93 °C, as specified in 5.2. Operating temperatures higher than 93 °C require special design considerations – consult with the manufacturer.

5. Material Requirements

5.1 *General*—Crosslinked polyethylene materials meeting the requirements specified in Section 5, are primarily defined by means of color, UV protection, density, degree of crosslinking, and long-term strength tests specified in Section 6.

5.2 Material Performance and MRS/CRS Requirements:

5.2.1 PEX pipe shall be made from polyethylene materials meeting the MRS requirements of 4.1, which have been crosslinked during the pipe manufacturing process, such that the pipe meets the performance requirements of Section 6.

5.2.2 To establish the maximum operating temperature, the manufacturer shall determine the CRS at that temperature, as discussed in Appendix X2. The PEX pipe shall have a 60 °C CRS at 50 years of at least 5.0 MPa.

NOTE 3—CRS times can range from 5 years to 100 years, and CRS temperatures can range from 0 °C to 93 °C.

5.3 *Color*—Pipe made in accordance with this specification is permitted to be colored using any commercially available colorant. Pipe made in accordance with this specification is also permitted to contain no colorant.

5.3.1 Pipe made in accordance with this specification is permitted to have co-extruded PEX color stripes or PEX layers of differing colors from the primary color of the PEX pipe. These stripes or layers are on the OD of the pipe.

5.3.2 The PEX material used in the stripe or layer shall be the same type material as specified in 5.2 for the PEX pipe. If PEX pipe is to have colored stripes or colored layer, the MRS testing specified in 5.2 shall be conducted on pipe samples with colored stripes or colored layer.

NOTE 4—Choice of color for stripes or pipe is subject to the end use application of the pipe.

5.4 UV Protection:

5.4.1 If the carbon black content in the pipe is less than 2.0 %, the pipe shall be weathered 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.

NOTE 5—Generally, the acceleration factor for accelerated weathering is between 3.75 to 4.4 times the number of test hours.