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: F3597 – 23

Standard Specification for MRS-Rated Metric- and Inch-sized Crosslinked Polyethylene (PEX) Pressure Pipe for Oil and Gas Producing Applications[1]

This standard is issued under the fixed designation F3597; 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 ISO 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, chemical resistance, minimum operating temperature, degree of crosslinking, squeeze-off, and hydrostatic burst pressure. Requirements for pipe markings are also given. The pipe covered by this specification is intended for pressure or non-pressure oil and gas producing applications such as conveying oil, dry or wet gas, gas gathering, multiphase fluids, and non-potable oilfield water. This specification does not cover gas distribution applications.

NOTE 1—Gas gathering applications where the pipe size is greater than NPS 8 may be subject to PHMSA design, material, and installation requirements.

1.2 This specification also includes requirements for qualifying joints made using polyethylene electrofusion fittings (such as Specification F3373) and PEX pipe. Fittings to be used with PEX pipe manufactured to this specification are in Specification F2829. Installation considerations are in X2.2.

NOTE 2—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 shall only be in SI units for conversion to the pipe material designation (for example PEX material in pipe form with an MRS of 8 MPa is designated 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]

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

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

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.68 on Energy Piping Systems.

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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.

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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
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
F2657 Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing
F2829 Specification for Metric- and Inch-Sized Fittings for Crosslinked Polyethylene (PEX) Pipe
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 *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 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.

2.5 *PPI Publications:*[5]

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), n*—the categorized lower prediction limit (LPL) of the long-term hydrostatic strength in the circumferential, or hoop direction as established by ISO 9080 and ISO 12162.

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($_{\theta,t}$), n*—the categorized lower prediction limit (LPL) of the long-term hydrostatic strength at a specified temperature and time as determined in accordance with ISO 9080 and ISO 12162.

3.2.2.1 *Discussion*—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. The CRS for PEX pipe is only determined after the MRS is established. CRS times range from 5 years to 100 years, and CRS temperatures range from 0 °C to 93 °C.

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 of at least 1.25, 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

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

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

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

TABLE 1 Material Designations For PEX Pipe

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

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those represented in the lower predictive limit. The minimum overall design coefficient (C_{min}) for oil and gas producing applications is 1.25, based on the C_M value of 1.25 specified in ISO 12162 and when CA is 1.0. The design engineer may add additional application coefficients, depending on the application, as shown below. See Appendix X1 for further discussion on design coefficients.

$$C = C_M \times C_A = 1.25 \times C_{A1}, \text{ or} \quad (1)$$

$C = 1.25 \times C_{A1} \times C_{A2}$ if there are multiple application coefficients

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

3.2.5.1 *material design coefficient (C_M), n*—a 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. Adding additional application coefficients is left to the design engineer to incorporate via appropriate design codes, national regulations or manufacturers recommendations, and is dependent on location of the pipeline, temperature, type of fluid being conveyed, and installation method.

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

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

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.

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

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

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

$$MOP = 2(C\ R\ S)/[(R - 1)(C)], \quad (4)$$

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

where:

σ_S = design stress, MPa
MOP = maximum operating pressure, MPa
D_o = average outside diameter, see Table 2 (mm) or Table 3 (in.)
t = minimum wall thickness, see Table 4 (mm) or Table 5 (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*—For DN sizes, the average outside diameter (D_0) is the arithmetic average calculated from the minimum and maximum outside diameters specified in Table 2.

TABLE 2 Outside Diameters and Tolerances for DN size PEX Pipe[A]

DN Size	Minimum outside diameter (mm)	Maximum outside diameter (mm)	Maximum of absolute out–of–roundness[B] (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] Small pipe diameters have minimum wall thicknesses values greater than the calculated value based on DR or SDR.
[B] Values are consistent with ISO 14531-1.

TABLE 3 Outside Diameters and Tolerances for NPS PEX Pipe

NPS	Average Outside Diameter in.	Tolerances for Average Diameter (±) in.	Maximum of absolute out– of-roundness 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

3.2.8 *material designation, n*—As used in this standard, the material designation for PEX pipe consists of the abbreviation

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TABLE 4 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 5 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.

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 1.

4. Pipe Classification

4.1 *General*—This specification covers two PEX material designations – PEX 80 with an 8.0 MPa MRS and PEX 100 with a 10.0 MPa MRS. 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.

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

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