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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.

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

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:

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

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

where:

σ_S	=	design stress, MPa
MOP	=	maximum operating pressure, MPa
D_o	=	average outside diameter, see Table 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

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

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 stated in 5.2. Operating temperatures higher than 93 °C require special design considerations – consult with the manufacturer.

5. Material Requirements

5.1 *General:*

5.1.1 All test specimens shall be conditioned and sampled in accordance with 7.1, 7.2, and 7.3.

5.1.2 Materials used to make PEX pipe shall meet all the requirements specified in Section 5. Materials for PEX pipe are primarily defined by means of MRS and CRS, color, UV protection, and density.

5.2 *Material MRS/CRS Requirements:*

5.2.1 The material, including and colorants or UV stabilizer, used to make PEX pipe shall meet the PEX 80 or PEX 100 material designation determined in accordance with ISO 9080 and ISO 12162 when tested in the form of pipe, as shown in Table 1, when conditioned in accordance with 7.1.

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

5.3 *Color:*

5.3.1 Materials using carbon black as both a colorant and UV stabilizer to make black PEX pipe shall contain 2.0 % to 3.0% well dispersed carbon black (such as N110 or N550) as a colorant/stabilizer.

5.3.2 Materials using carbon black as only a colorant (less than 1.5% carbon black) shall meet the UV requirements of 5.4.

5.3.3 Materials using color pigments as a colorant shall meet the UV requirements of 5.4.

5.3.4 Materials used in PEX colored stripes shall be the same type material as specified in 5.2 for the PEX pipe.

NOTE 3—Choice of color for stripes or pipe is subject to agreement between manufacturer and purchaser.

5.4 *UV Protection:*

5.4.1 If the material uses a colored pigment or if the carbon black content in the material is less than 1.5 %, PEX pipe shall be weathered in accordance with one of these test methods: 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 4—Generally, the acceleration factor for accelerated weathering is between 3.75 to 4.4 times the number of test hours.

5.4.2 The UV requirement of 5.4.1 is not applicable if the content of well-dispersed carbon black is 2.0 % to 3.0% as measured by Test Method D1603 or Test Method D4218 (see ISO 14531-1 Table 8). To demonstrate good carbon black dispersion the PEX pipe shall meet the ISO 14531-1 dispersion requirement of less than or equal to grade 3 when measured in accordance with ISO 18553, or in accordance with an equivalent ASTM test method for carbon black dispersion, such as Test Method D5596. Black material with 2.0 % to 3.0 % carbon black shall be considered stabilized and protected against deterioration from unprotected UV exposure for at least 10 years.

5.5 *Density*—When determined in accordance with 7.4, the material prior to crosslinking shall have a minimum density of 0.926 g/cc.

5.6 *Rework Material*—PEX rework shall not be used as a material in the manufacture of PEX pipe made in accordance to this specification.

6. Pipe Requirements

6.1 *Conditioning*—All test specimens shall be conditioned and sampled in accordance with 7.1, 7.2, and 7.3.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 2 for DN sizes or Table 3 for NPS, when measured in accordance with 7.5.1.

6.2.2 *Out-of Roundness*—The out-of-roundness of pipe made in accordance with this specification shall be less than or equal to the values specified in Table 2 or Table 3 when measured in accordance with 7.5.2 or Test Method D2122 or ISO 3126.

6.2.3 *Wall Thickness and Tolerances*—The wall thickness for pipe made in accordance with this specification shall be as shown in Table 4 for DN sizes and in Table 5 for NPS, when measured in accordance with 7.5.3. The tolerance for all wall thicknesses is plus 12 %.

6.3 *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.

6.4 *Degree of Crosslinking:*

6.4.1 When tested in accordance with 7.6.1, the degree of crosslinking for PEX pipe shall meet the following specified requirements. The minimum percentage crosslinking value shall be 65 % for PEX compounds crosslinked using silanes or radiation, or 70 % for PEX compounds crosslinked using peroxides. The maximum degree of crosslinking shall be 89 % for all PEX types.

6.4.2 In addition, for pipe with a wall thickness greater than 0.5 in. or 12.7 mm, the degree of crosslinking shall be measured in accordance with 7.6.2. The degree of crosslinking at each of the tested points of all thick-wall pipe tested in accordance with 7.6.2 shall meet the requirements specified in 6.4.1.

6.5 *Minimum Hydrostatic Burst Pressure (Quick Burst)*—The pipe shall fail in a ductile manner when tested in accordance with 7.7. The time of testing of each specimen shall be between 60 s and 70 s. For pipe sizes above 4 in. [110 mm] nominal diameter, the testing lab shall be allowed to replace the quick burst test by the apparent ring tensile strength test in 6.6.

6.6 *Apparent Ring Tensile Strength*—- For pipe sizes of DN 110 and larger or NPS 4 and larger testing in accordance with 7.8 is permitted to replace testing in accordance with 7.7. The

minimum apparent tensile strength at yield when determined in accordance with 7.8 shall be 17.4 MPa for PEX pipe with an MRS of 8 MPa or 20.0 MPa for PEX pipe with an MRS of 10 MPa.

6.7 *Qualification Tests*—Testing to establish chemical resistance (in accordance with, 6.8), sustained pressure strength (in accordance with, 6.9), slow crack growth resistance (in accordance with, 6.10), minimum operating temperature (in accordance with, 6.11), squeeze off (in accordance with, 6.12), and qualification for electrofusion joining (in accordance with, 6.13) shall be performed when first using a material formulation and/or crosslinking process for PEX pipe production. Re-testing shall be required for a material formulation or crosslinking process change.

6.8 *Chemical Resistance*—The material shall not increase in weight more than 0.5 % (1.0 % for toluene in methanol) when tested in accordance with 7.9. For ring tensile testing in accordance with 7.9, the apparent tensile yield strength shall not decrease by more than 12 %.

NOTE 5—This test is only an indication of what will happen as a result of short-term exposure to these chemicals. For long-term results, additional testing is should be considered.

6.9 *Hydrostatic Sustained Pressure Strength*—Pipe samples tested for 1000 h in accordance with 7.10 shall not fail as defined in Test Method D1598. The test pressure (P) shall be based on the following equation:

$$P - 2S/(D_o/t - 1) \quad (6)$$

where:

P = Test pressure, MPa
S = Hoop stress in accordance with Table 6
D_o = Average outside diameter in accordance with Table 2 or Table 3
t = minimum wall thickness, in accordance with Table 4 or Table 5

NOTE 6—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.

6.10 *Slow Crack Growth Resistance*—NPS 4 or 125 mm PEX pipe shall meet the following slow crack growth requirement after it has been crosslinked. There shall be no failure before 5000 hours when tested in accordance to Test Method D1598 at 80 °C at 8.0 bar for PEX 80 or 9.2 bar for PEX 100.

6.11 *Pipe Minimum Operating Temperature:*

6.11.1 The minimum operating temperature for pipe shall be established by testing in accordance with 7.11.

6.12 *Squeeze-off*—Squeeze-off testing shall only be conducted for pipe sizes, wall thicknesses, squeeze procedures, and conditions deemed suitable for squeeze-off in service by the pipe manufacturer. The PEX pipe shall be conditioned to assure it is at the minimum operating temperature, then squeezed-off at this temperature in accordance with ISO 14531-1 Annex D. Samples of pipe that have been subjected to squeeze-off shall then not fail when tested at 95 ºC for 1000 hours in accordance with Test Method D1598 or ISO 1167 at the hoop stress stated in Table 7 for the material.

6.13 *Qualification of PEX Pipe for Use with Polyethylene Electrofusion Joints*—For PEX pipe that is deemed suitable by the pipe manufacturer for joining to polyethylene (PE) electrofusion fittings, the pipe manufacturer shall qualify the PEX pipe by testing joints made with PE electrofusion fittings and PEX pipe meeting this standard, and assuring that these joints meet the performance requirements of the PE electrofusion fitting standard, such as Specification F3373.

7. Test Methods

7.1 *Conditioning*—Unless otherwise specified, condition the specimens for not less than 40 h prior to testing in accordance with Procedure A of Practice D618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ±1 °C and ±10 % relative humidity.

7.2 *Test Conditions*—Conduct the test in the standard laboratory atmosphere, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be ±1 °C and ±10 % relative humidity.

7.3 *Sampling*—A sufficient quantity of pipe, as agreed upon by the purchaser and the seller, shall be selected and tested to determine conformance with this specification. In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

7.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe that is at least one pipe diameter away from an end closure.

7.4 *Density*—Determine the density of the pipe compound in accordance with Test Method D1505 or Test Methods D792, using three specimens.

7.5 *Dimensions and Tolerances*—Use any length of pipe to determine the dimensions. Measurements shall be taken in accordance with Test Method D2122 or ISO 3126.

7.5.1 *Outside Diameter*—Measure the outside diameter of the pipe in accordance with Test Method D2122 or ISO 3126 at 300 mm from the pipe end. The referee method of measurement is to be by circumferential wrap tape.

TABLE 6 Hoop Stress Values for Hydrostatic Sustained Pressure Test

Temperature °C MPa	Material Designation for Pipe	Hoop Stress[A]
20	PEX 80	8.3
20	PEX 100	10.4
95	PEX 80	3.7
95	PEX 100	4.7

[A]Hoop stress (MPa) values are consistent with ISO 14531-1.

TABLE 7 Chemicals for Chemical Resistance Testing

Chemicals	Concentration (% by volume)
Mineral oil (USP)	100
Tertiary-butyl mercaptan	5 in mineral oil
Antifreeze agents (at least one shall be used):	
Methanol, or	100
Ethylene glycol	100
Toluene	15 in methanol

7.5.2 *Out-of-roundness*—The tolerance for out-of roundness shall apply only to pipe prior to shipment. The average of four (4) maximum and minimum diameter measurements at any cross section, measured by micrometer or vernier caliper, is permitted for quality control checks only.

7.5.3 *Wall Thickness*—Make micrometer measurements of the wall thickness in accordance with Test Method D2122 or ISO 3126 to determine the maximum and minimum values. Measure the wall thickness at both ends of the pipe to the nearest 0.001 in. or 0.025 mm.

7.6 *Degree of Crosslinking:*

7.6.1 Prepare specimens by placing a pipe sample in a lathe with automatic feeding. Shave strips that consist of the full wall thickness of the pipe. The strip thickness shall be 0.1 mm ± 0.05 mm, which is obtained by setting the lathe feeding accordingly. Test the specimens in accordance with Test Methods D2765, Method B. Alternatively, for routine quality control and monitoring only, testing in accordance with Test Method F3203 is permissible. For either test method, the only deviation permitted is test specimen preparation which shall be as specified above. For the purpose of this specification the degree of crosslinking is equal to the measured gel content.

7.6.2 In addition, for pipe with a wall thickness greater than 0.5 in. or 12.7 mm, the degree of crosslinking shall be measured at four points separated by 90° in the middle of the wall. For one of these points, measurements shall be taken at three points across the wall thickness. Fig. 1 shows the locations where the gel content samples shall be collected relative to each other. Collect shaving samples, about 0.10 mm thick, by drilling a hole in the axial pipe direction with a 3 mm drill bit to collect a 0.2 gram – 0.4 gram sample size.

7.7 *Minimum Hydrostatic Burst Pressure (Quick Burst)*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599. Pressures shall be as calculated using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress. Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599.

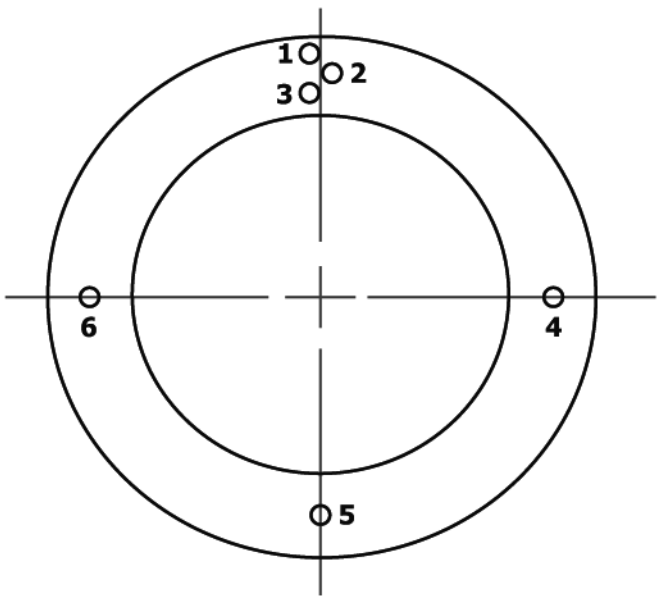

FIG. 1 Sample Location For Degrees Of Crosslinking Test On Thick-Wall Pipe

7.8 *Apparent Tensile Properties*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D2290, Procedure B for smaller diameters. Due to toe-in effects and ID variability, Procedure D or E shall be used for larger diameters. The speed of testing shall be 12.7 mm/min. Cut "ring" specimens from pipe. Test a minimum of five specimens. This method is applicable to all pipe NPS 4 and larger and DN 110 and larger.

7.9 *Chemical Resistance*—Determine the resistance to the chemicals listed in Table 7 in accordance with Practice D543. The test specimen shall be a ring of pipe cut to the ring dimensions specified in 7.8.

7.9.1 Test five specimens with each chemical. Weigh the specimens to the nearest 0.005 g and completely immerse them in the chemicals for 72 h. On removal from the chemicals, wipe the specimens with a clean dry cloth. Condition in air for 2 to 2 ¼ h and reweigh. Calculate the increase in weight to the nearest 0.01 % on the basis of initial weight. Test the specimen in tension in accordance with 7.8 within ½ h after weighing. Examine the weight and apparent tensile strength of each specimen for conformance to the requirement in 6.8. **Warning—**Because of the possible toxicity of these reagents, refer to the Material Safety Data Sheet on each of these reagents before using or handling them.

NOTE 7—This pipe test is only an indication of what will happen as a result of short-term exposure to these chemicals. For long-term results, additional testing is required.

7.10 *Hydrostatic Sustained Pressure Test*—Condition pipe specimens in accordance with 7.1. The size of pipe sampled for this test shall be less than or equal to NPS 4 or DN 110. Select the test specimens at random. Test individually with water at the specified temperature and under the pressures given in 6.9. Each specimen shall be at least ten times the nominal diameter in length, but not more than 900 mm between end closures and containing the permanent marking on the pipe. Test six specimens at each temperature. Condition the specimens for at least 2 h to within ± 2 °C of the specified test temperatures. Maintain the specimens at the stresses indicated in Table 6 for the appropriate temperatures. Hold the stress as closely as possible, but within ± 0.1 MPa. Maintain the test temperatures within ± 2 °C of the specified temperature. Test in accordance with Test Method D1598 or ISO 1167 except maintain the pressure at the values given in 6.9. Failure of at least one of six specimens tested at either temperature constitutes failure in the test.

7.11 *Minimum Operating Temperature*—Determine the Small-Scale-Steady-State (S-4) RCP critical temperature in accordance with ISO 13477 at a constant hoop stress of 6.4 MPa for PEX 80 or 8.0 MPa for PEX 100 on a single pipe size. The minimum pipe size and wall thickness is DN 110 SDR 11. The minimum operating temperature shall be equal to the S-4 critical temperature.